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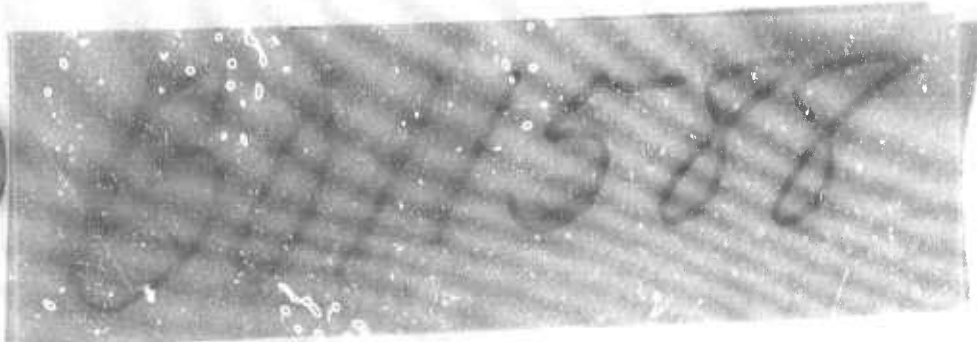
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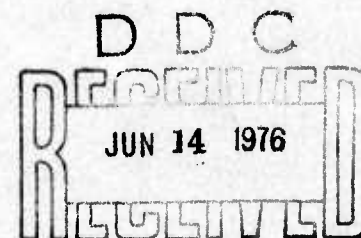


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ALCOR High Altitude Weather Scans
AFCRL/A.N.T. Report No. 1

ARNOLD A. BARNES, Jr.
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31 December 1975



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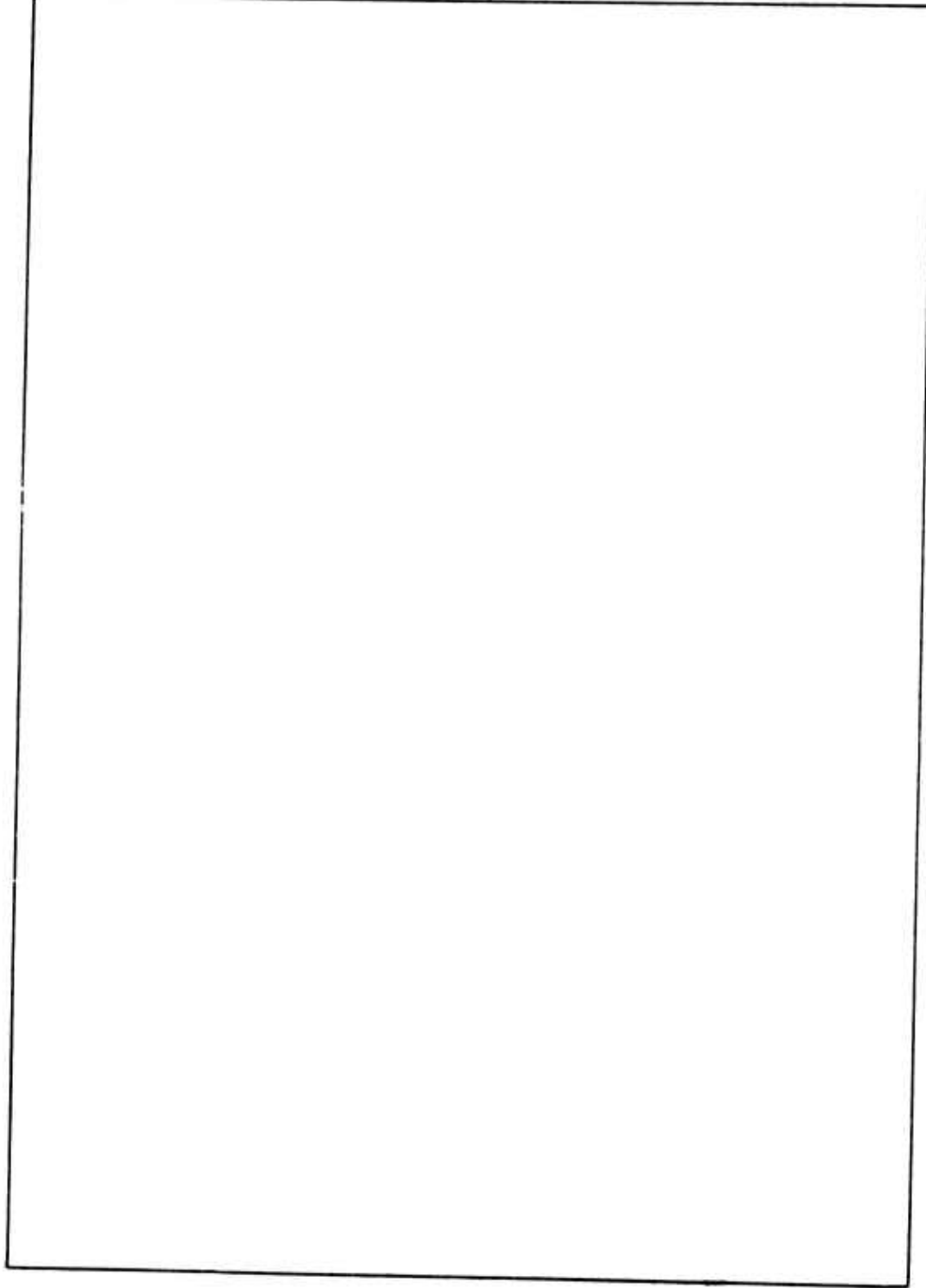
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ALCOR High Altitude Weather Scans

AFCRL/A.N.T. Report No.1

1. INTRODUCTION

At a meeting at Los Angeles Air Force Station on 29 January 1975 with Air Force Cambridge Research Laboratories (AFCRL), and the Space and Missile Systems Office (SAMSO)/Advanced Ballistic Reentry Systems (ABRES) representatives, AFCRL was requested to supply information on the ice water content (IWC) to be found above 39,000 ft at Kwajalein Missile Range (KMR). This information was needed by SAMSO to determine the altitude requirements for a high altitude weather sampling aircraft for the Advanced Nosetip Test (A.N.T.) program. Having accepted the task, AFCRL supplied to ABRES on 17 February 1975 information on the IWC at KMR as determined by weather scans taken by ARPA Lincoln C-Band Observables Radar (ALCOR) in support of the Minuteman program. This information was utilized by SAMSO in the decision to outfit a Learjet, Model 36, for the high altitude weather sampling.

2. DESCRIPTION OF DATA

The source of data utilized in this study was the listings of the WSI scans taken by ALCOR in support of Minuteman during March to April and during July to October 1974. Two types of scans were made: Trajectory scans - taken along

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nominal RV trajectories but at a speed approximately one-fifth that of the RV: vertical scans - taken along a vertical line above a designated point. All scans, made at speeds slow enough to obtain usable weather radar data, were taken between ground noise clutter and a height of 20 kilometers.

ALCOR is a chirp (that is, frequency modulated) radar, and the weather scans were taken at either 100 or 200 pulses per second. The data were transmitted from the ALCOR computer to the Pacific Range Electromagnetic Signature Studies (PRESS) computer once every tenth of a second. Since only the data from the last pulse were transmitted, the effective PRF as seen at PRESS was 10 pulses per second. On the other hand, the chirp aspects of ALCOR provide some smoothing to the usual pulse-to-pulse variability seen when using short pulse CW weather radars. Data received at PRESS were averaged over 1 sec, and the mean height and average radar reflectivity values (Z) were printed for each second. These data, in tabular form, have been utilized for this study.

Since the radar Z values do not give the IWC directly, some Z-M relationship must be assumed to convert the radar Z values to IWC values. For the Minuteman program, we used the only high altitude Z-M relationship available at that time, the one developed by Dr. Heymsfield¹ from PMS 1-D data taken in cirrus over the continental United States. This equation was included in the PRESS MOIST program for all scans taken starting in July 1974, and these M values were listed along with height, Z, and so on. Using a Hewlett Packard 65 hand-held computer (HP-65), we made the same calculations for scans taken during the March to April period.

Immediately, the question arises as to whether this is the correct Z-M relationship to use, and the first answer is no. Our experience at KMR has shown that there are day-to-day changes of the crystal habit at these altitudes.² The WB-57 F replicator showed such day-to-day variations. Also, as we watched on the WSR-57 weather radar, thunderstorms penetrated the tropopause, rising to 20-km altitude, and it was obvious that an assortment of rimed crystals created at lower levels was being transported to very high levels. The only way to determine the IWC in each individual case is to know the crystal habit in each case, that is, to develop a tailored Z-M relationship for each individual case, as was done on PVM-5. Since the aircraft crystal habit data were missing, this was not possible for the study. However, since we were looking for statistical answers as an end product, we used the Z-M relationship for bullets and columns in cirrus over the United States, as given by Heymsfield.¹

1. Heymsfield, A. J. (1973) The cirrus uncinus generating cell and the evolution of cirriform clouds, Ph. D. dissertation, University of Chicago.
2. Barnes, A. A., Jr., Nelson, L. D., and Metcalf, J. I. (1974) Weather documentation at Kwajalein Missile Range, 6th Conf. Aerosp. and Aeronaut. Meteor., Amer. Meteor. Soc., pp 66-69, AFCRL-TR-74-0430.

Further, if one relationship is to be used for this study, is the bullet and column the best one? At the present time, from the small amount of evidence available, we are forced to conclude that there is no Z-M relationship which we consider to be better suited for this particular high altitude study.

In Appendix D, we have listed all such WSI scans that we could find at AFCRL. It must be pointed out that there is a bias in the scans since they were usually taken when there was significant weather at KMR. The exceptions occurred at such times as when we were testing the scanning procedures, or testing the computer programs, or modifications to the computer programs. For each scan, or set of trajectory scans, we have listed the time, data, noise levels, and whether or not a plot is provided. The plots are included in Appendix A. For the vertical scans, we have given the range to the point where the vertical line intersects the surface. There were a number of different trajectories used in the program, but we have not tried to identify them. Some were close to ALCOR; some went into the lagoon; and some were to the east-south-east of Kwajalein Island.

3. DISCUSSION OF FIGURES

Appendix A contains plots of those scans that had detectable weather above 10 km. Each figure gives the data and time. The scans were not plotted above the first value which was thought to be in the noise. Since four people were plotting these scans, the reader will find differences as to where the cloud ends and the noise begins. On the other hand, this is not useless information, for one can then find the lower limit of detection of ALCOR when used as a weather radar.

Appendix B contains only one figure. Figure B1 shows the envelope of all the data plotted in Appendix A. Close inspection of the figures in Appendix A will show that the points above 15.5 km are probably close to the noise level. The tropopause is normally near 54,000 feet or 16.5 kilometers.

At the following selected altitudes, Appendix C contains plots of the IWC for the period March through October 1974.

Figure Number	Altitude	
	(km)	(ft)
C1	11.5	37,731
C2	12.0	39,372
C3	12.5	41,012
C4	13.0	42,653
C5	13.5	44,294
C6	14.0	45,934

The data seem to be divided into three different populations: March to April; July to August; and September to October. We feel that this is to be attributed to an improved capability to sample significant weather. The first period, March to April, represents the first attempt at a weather shot, and the difficulties of getting the right kind of weather were not known. Hence, the team was not operating at its maximum efficiency, and high IWC values were often missed. By the second period, July to August, everyone became cognizant of the difficulties in obtaining scans in heavy weather. As a consequence, more frequent and more timely scans were made.

By September, it had become obvious that as far as the operations were concerned, any forecast greater than six hours was only an outlook. This put the pressure on the range to bring the equipment up in a shorter amount of time. Consequently, we were able to get better data in the short-lived weather systems as they passed the Kwajalein Atoll.

On the 18th and 27th of September, Figures A31, A32, A35, and A36 show strong systems while Figure A37, on 3 October, shows a large variation in IWC values in just four hours.

4. CONCLUSIONS

If the A.N.T. program is going to require weather as severe as required for PVM 6/7, then we will have to wait for the passage of a fairly strong easterly wave. It is our opinion that it is almost hopeless to try and fire into individual thunderstorms because of forecasting and sampling problems. If we do fire into strong easterly waves, such as were successfully sounded by ALCOR in September and October 1974, then we should expect maximum IWC values and profiles similar to those shown in the Appendices.

References

1. Heymsfield, A. J. (1973) The cirrus uncinus generating cell and the evolution of cirriform clouds, Ph. D. dissertation, University of Chicago.
2. Barnes, A. A., Jr., Nelson, L. D., and Metcalf, J. I. (1974) Weather documentation at Kwajalein Missile Range, 6th Conf. Aerosp. and Aeronaut. Meteor., Amer. Meteor Soc., pp 66-69, AFCRL-TR-74-0430.

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Appendix A

Selected IWC Profiles

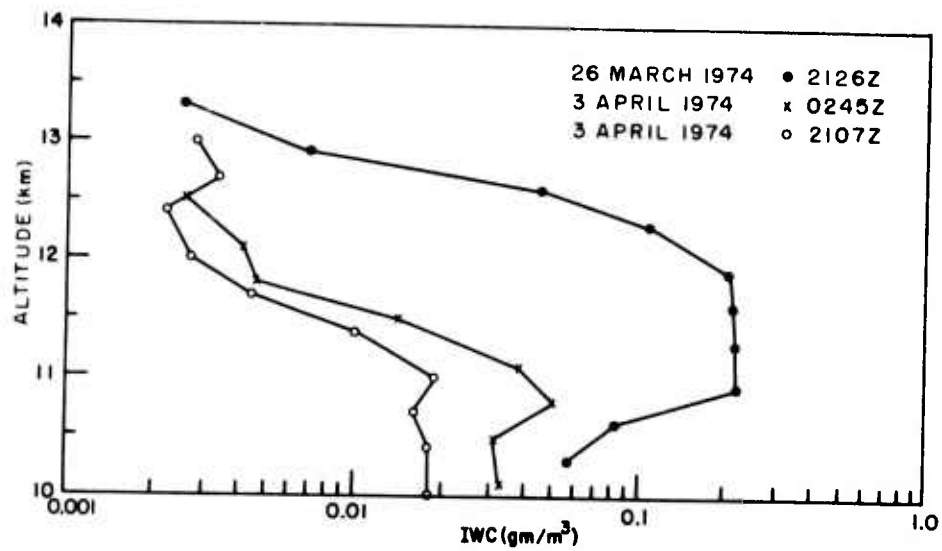


Figure A1. Ice Water Content vs Altitude; 26 March and 3 April 1974; Vertical Scans

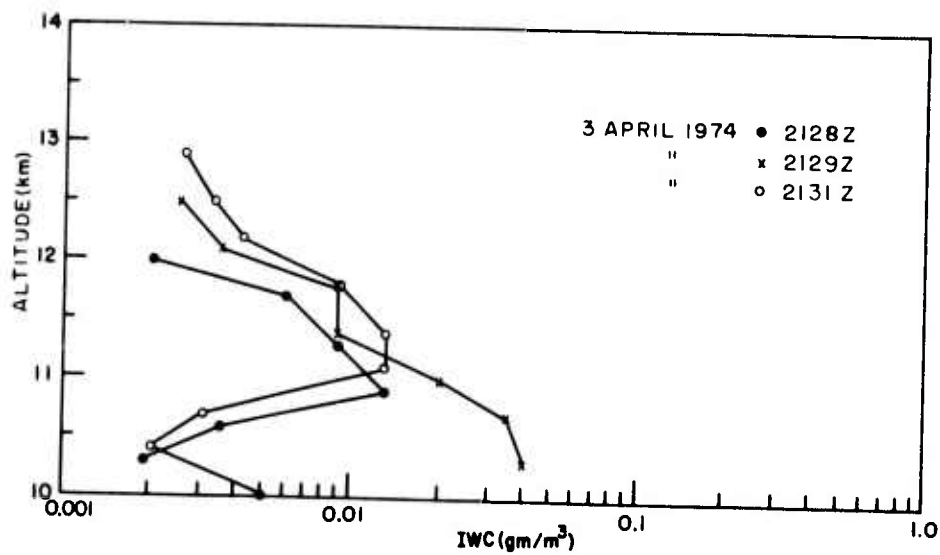


Figure A2. Ice Water Content vs Altitude; 3 April 1974; Trajectory Scans

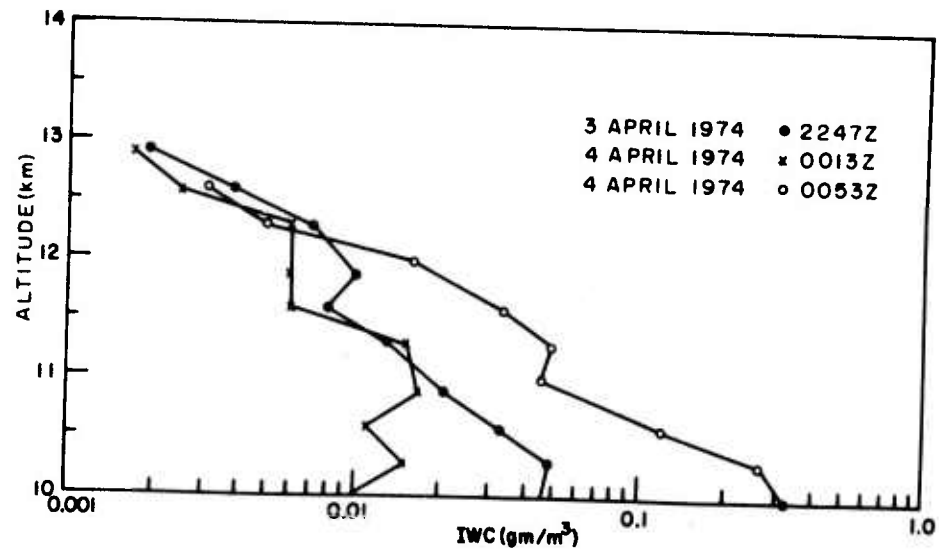


Figure A3. Ice Water Content vs Altitude; 3 and 4 April 1974; Vertical Scans

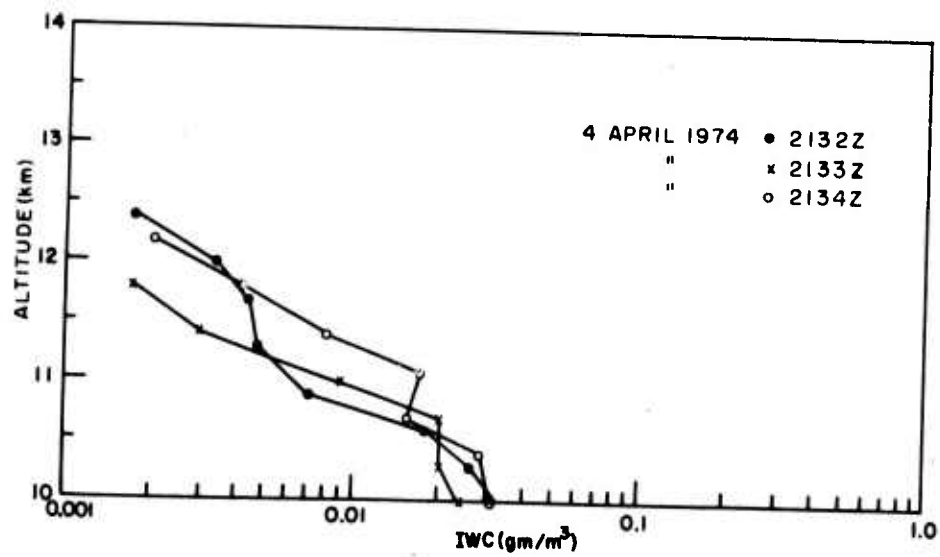


Figure A4. Ice Water Content vs Altitude; 4 April 1974; Trajectory Scans

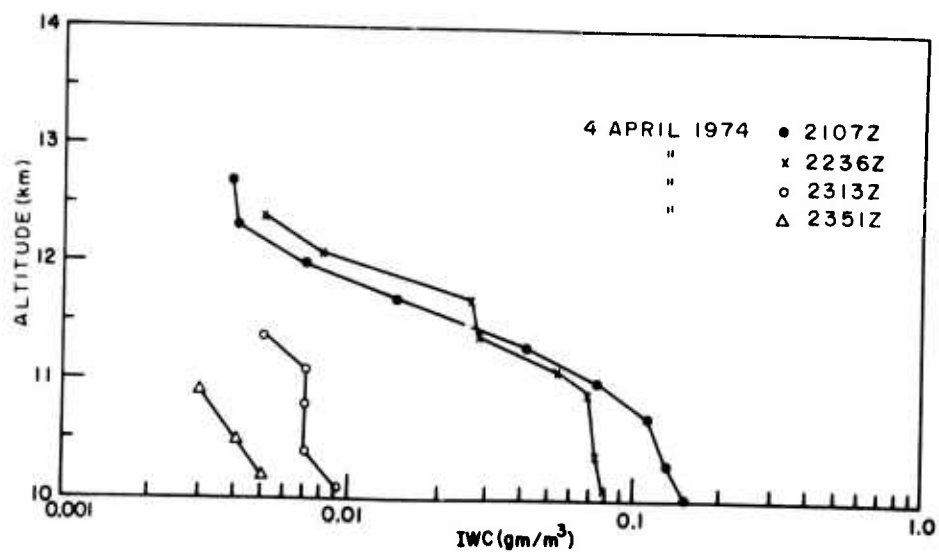


Figure A5. Ice Water Content vs Altitude; 4 April 1974; Vertical Scans

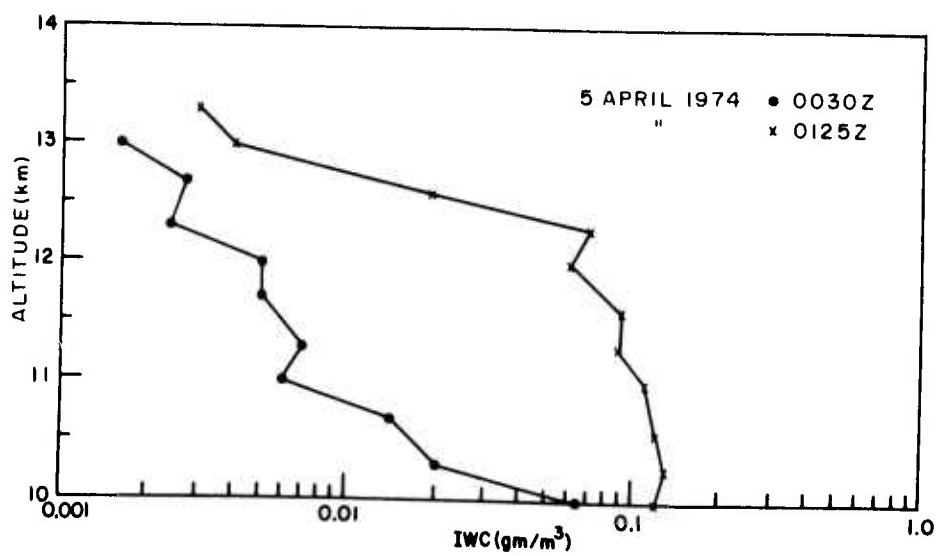


Figure A6. Ice Water Content vs Altitude; 5 April 1974; Vertical Scans

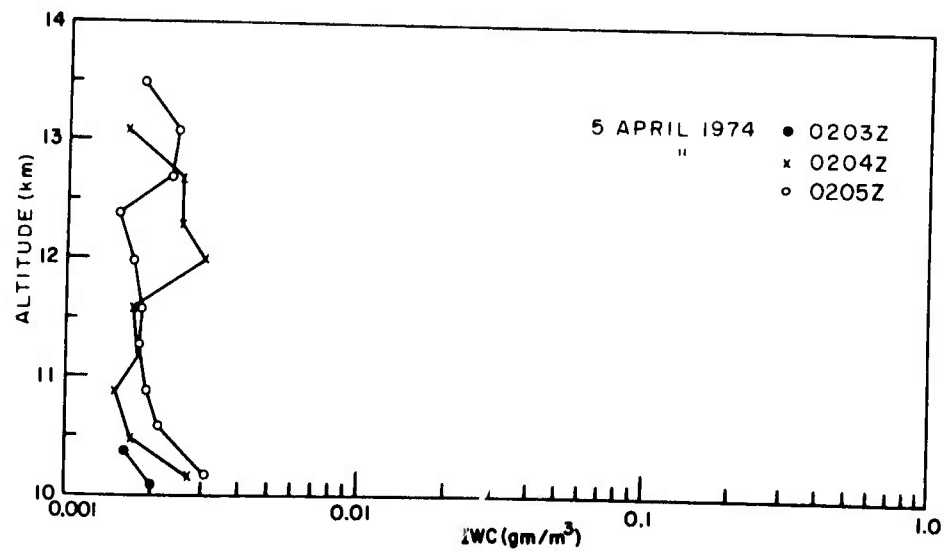


Figure A7. Ice Water Content vs Altitude; 5 April 1974; Trajectory Scans

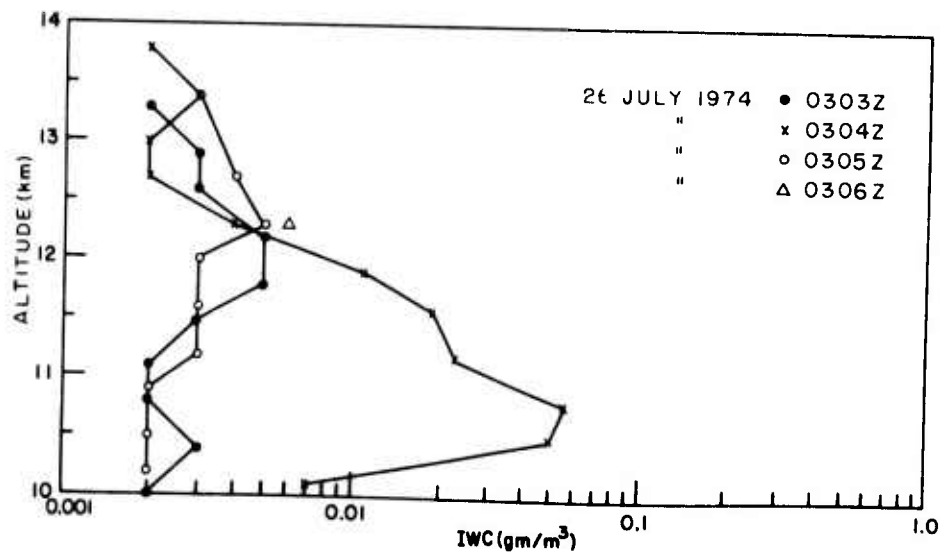


Figure A8. Ice Water Content vs Altitude; 26 July 1974; Trajectory and Vertical Scans

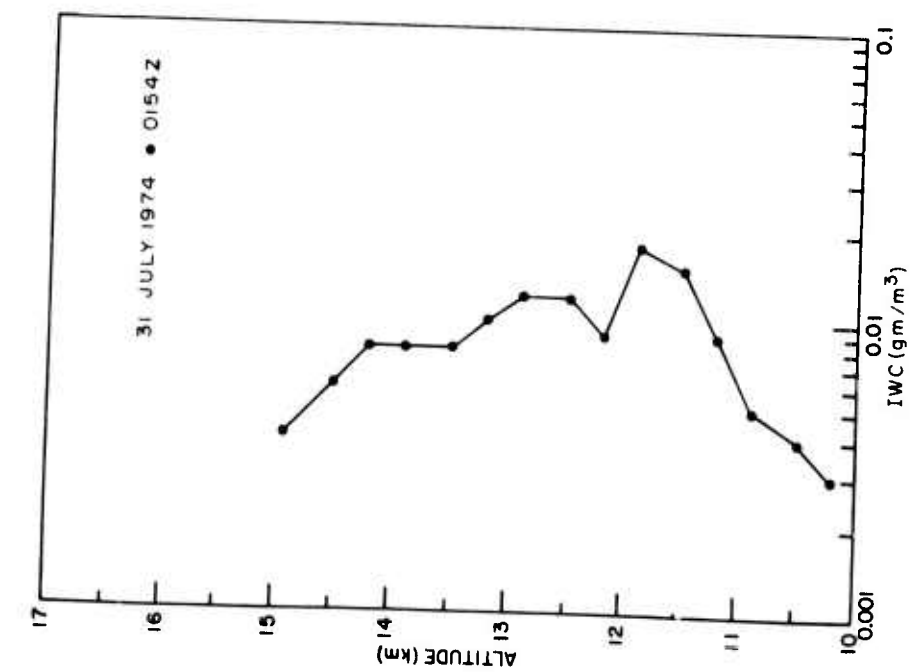


Figure A10. Ice Water Content vs Altitude; 31 July 1974; Vertical Scan

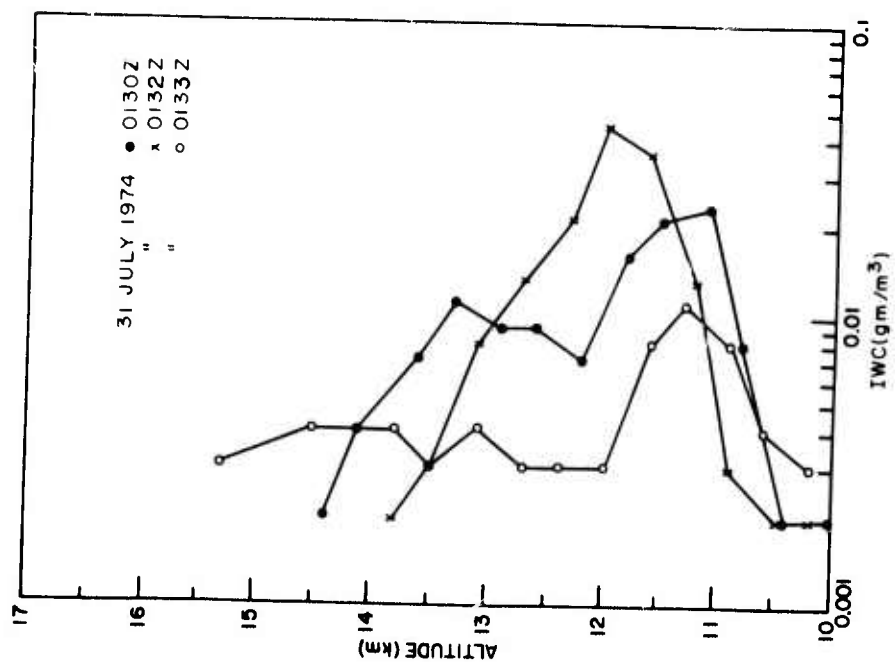


Figure A9. Ice Water Content vs Altitude; 31 July 1974; Trajectory Scans

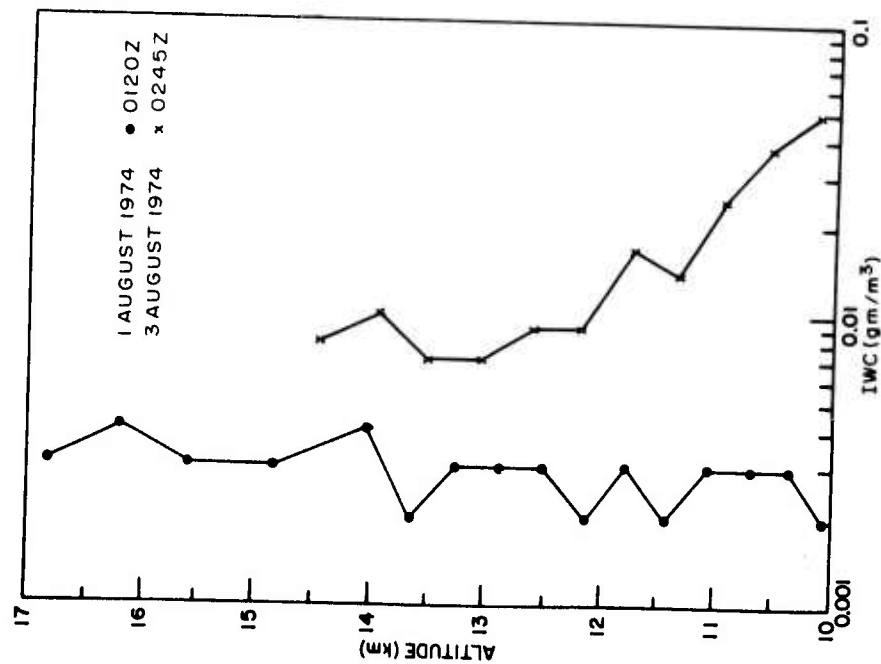


Figure A11. Ice Water Content vs Altitude:
1 and 3 August 1974; Trajectory Scans

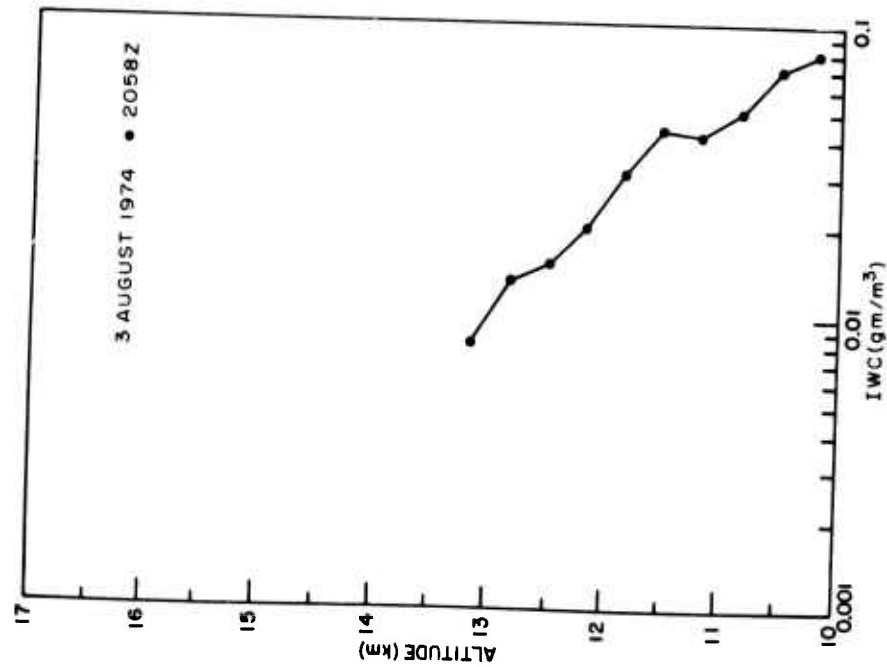


Figure A12. Ice Water Content vs Altitude:
3 August 1974; Vertical Scan

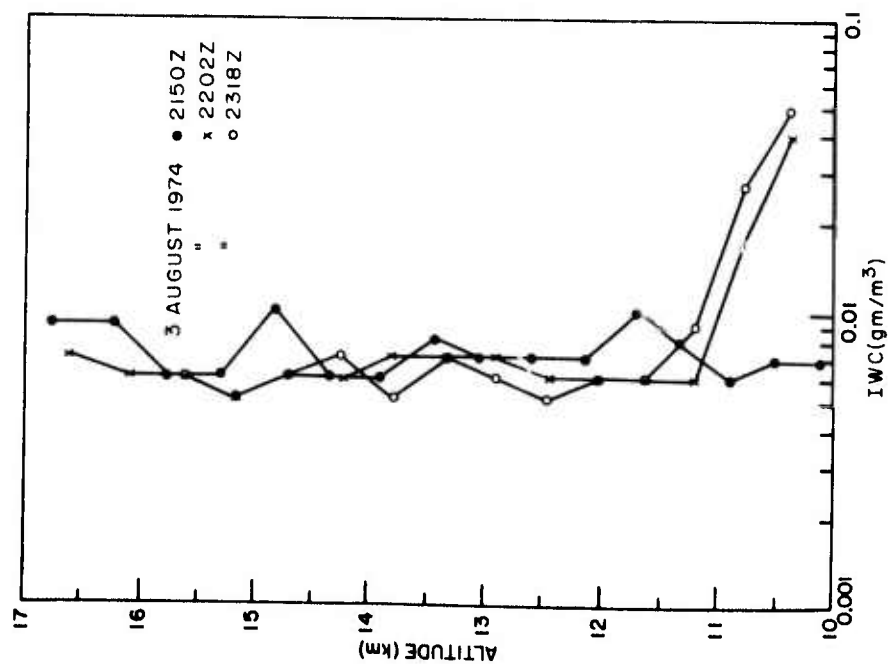


Figure A13. Ice Water Content vs Altitude;
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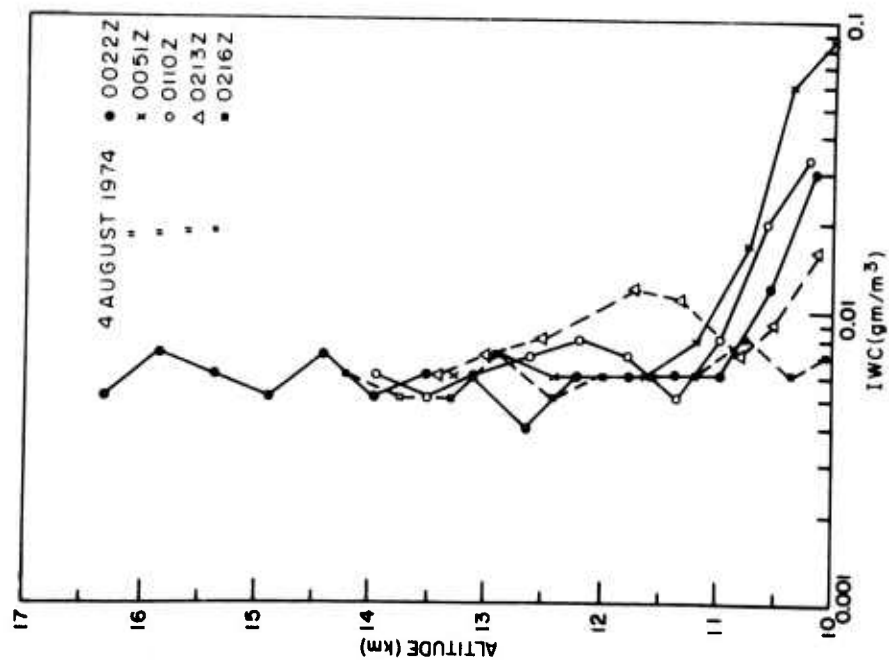


Figure A14. Ice Water Content vs Altitude;
4 August 1974; Trajectory Scans

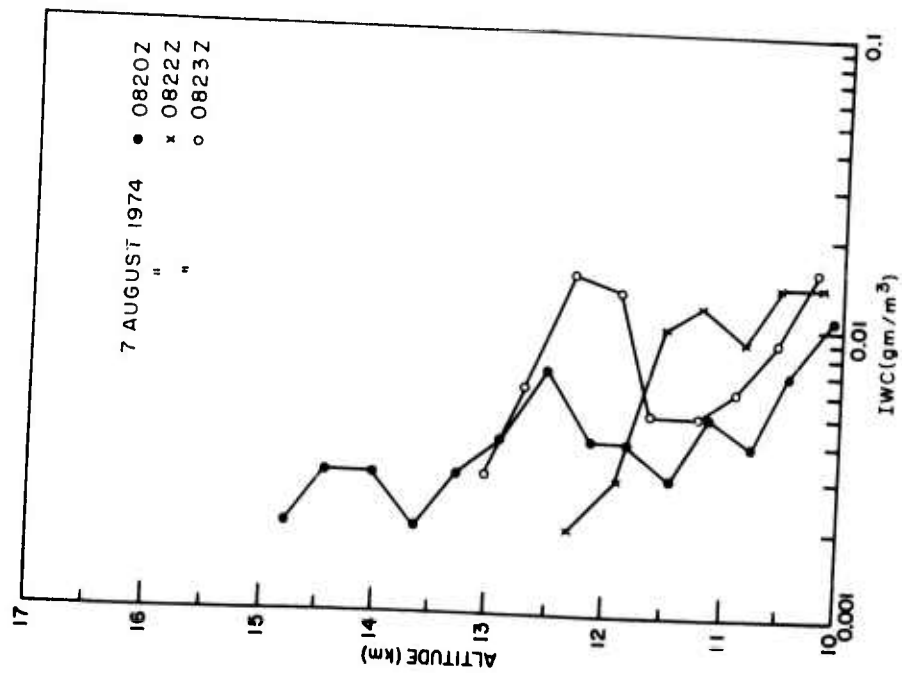


Figure A15. Ice Water Content vs Altitude;
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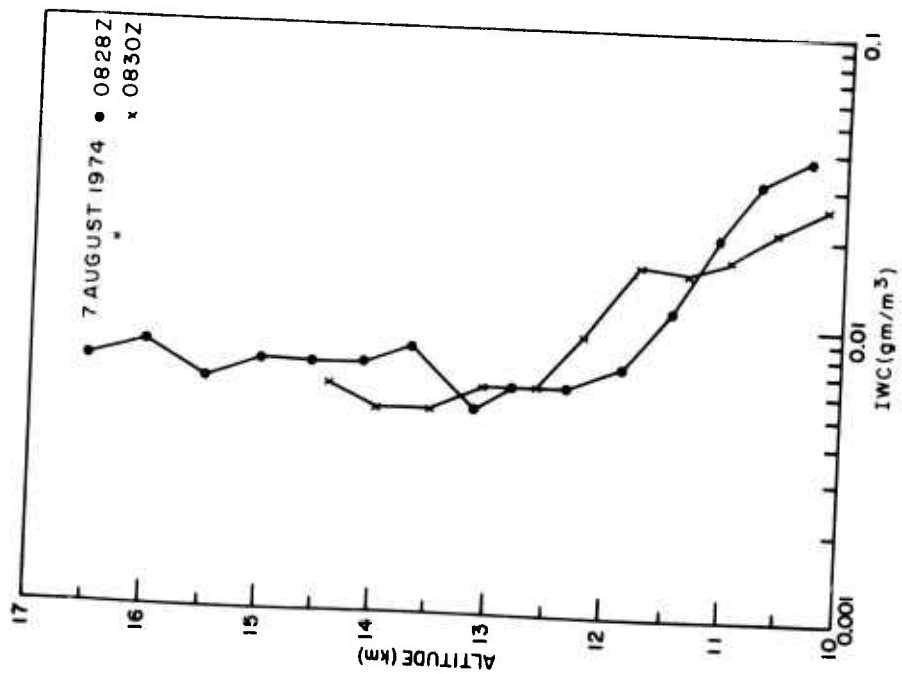


Figure A16. Ice Water Content vs Altitude;
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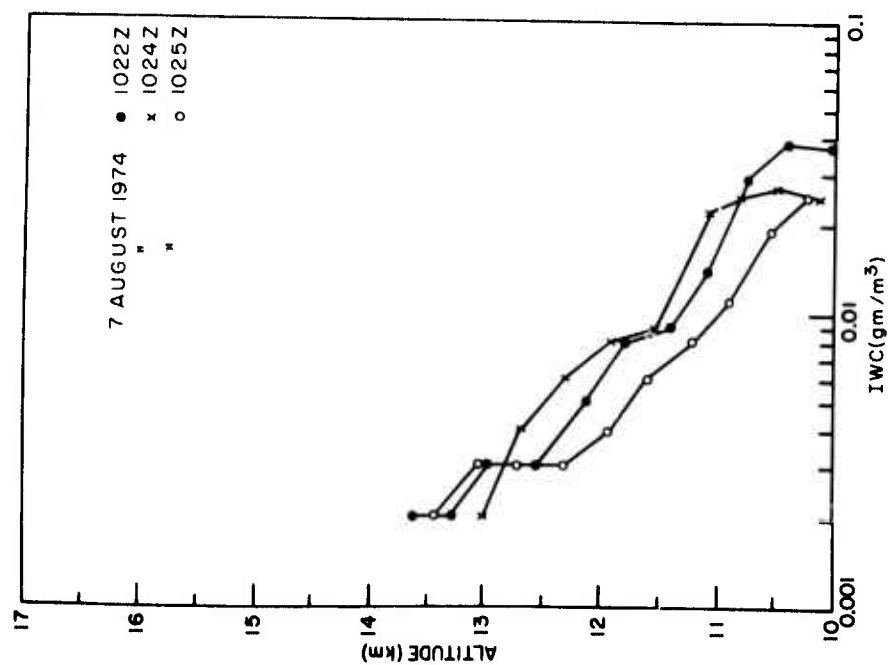


Figure A17. Ice Water Content vs Altitude;
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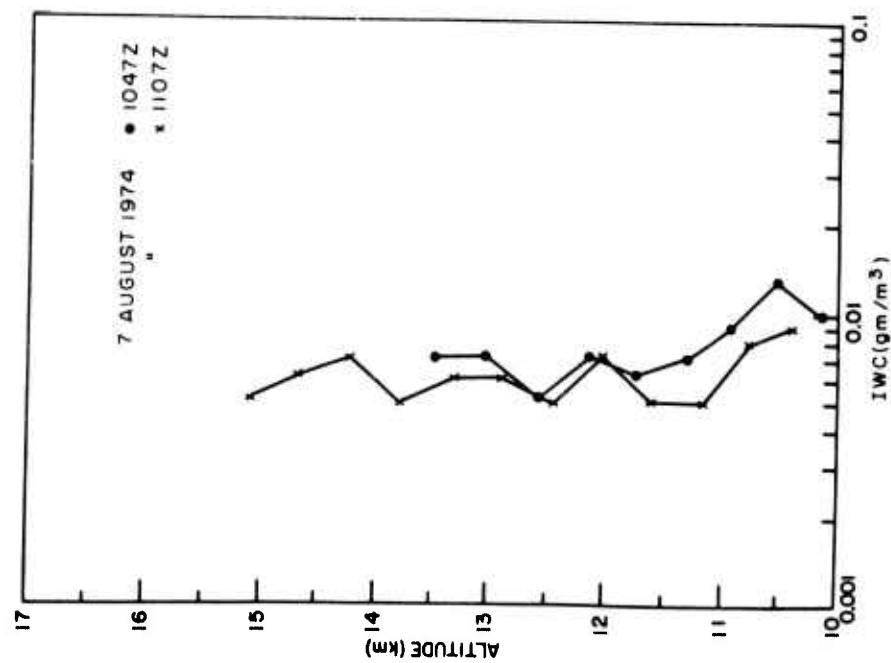


Figure A18. Ice Water Content vs Altitude;
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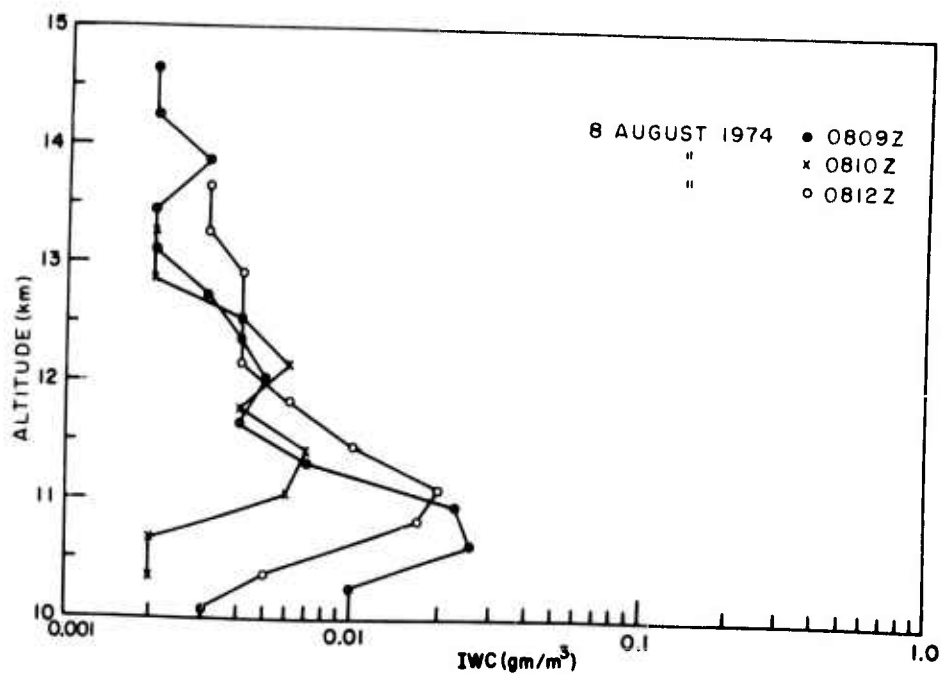


Figure A19. Ice Water Content vs Altitude; 8 August 1974;
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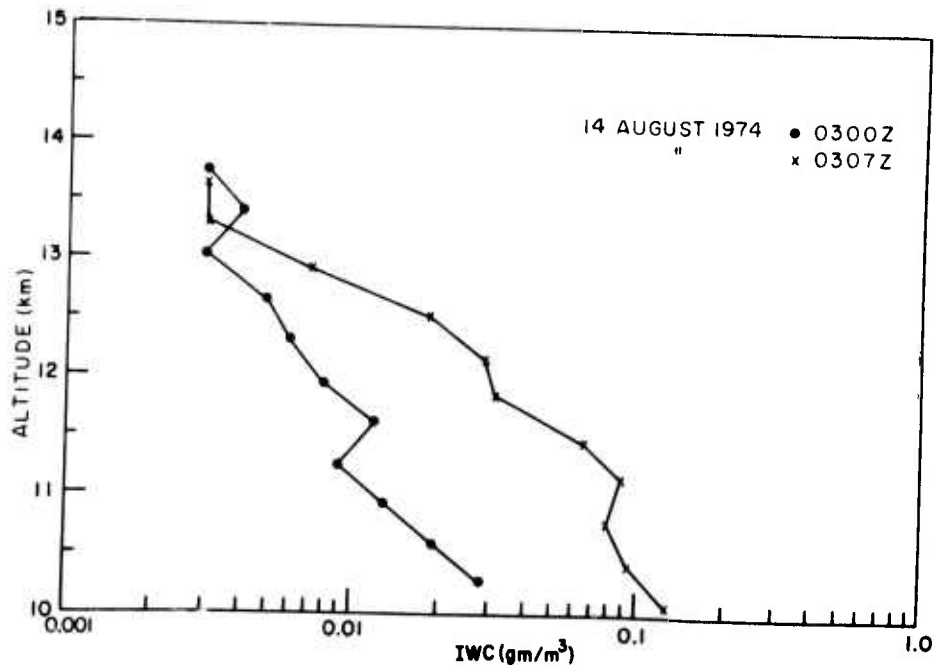


Figure A20. Ice Water Content vs Altitude; 14 August 1974;
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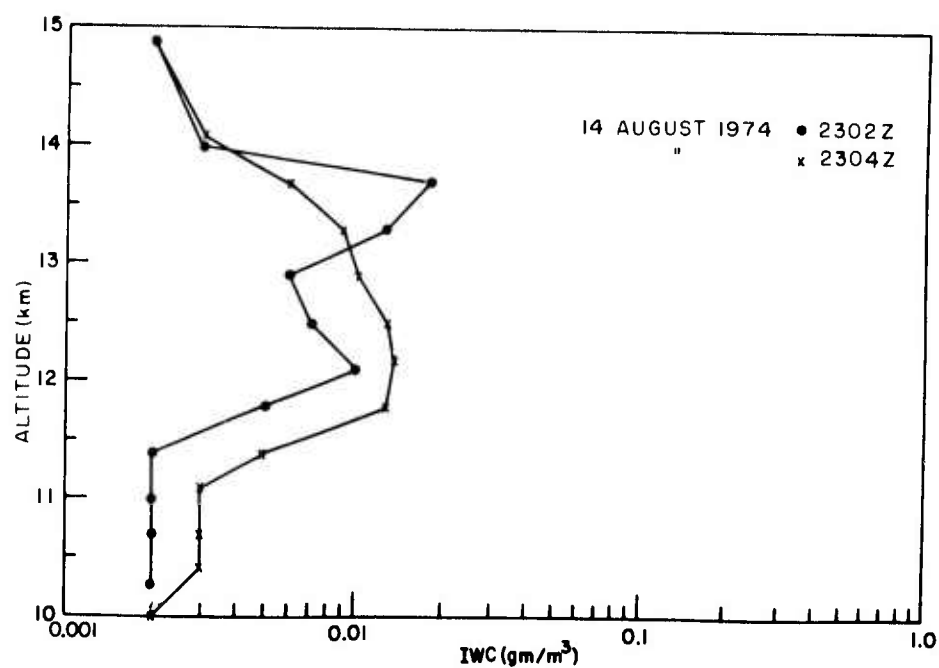


Figure A21. Ice Water Content vs Altitude; 14 August 1974; Trajectory Scans

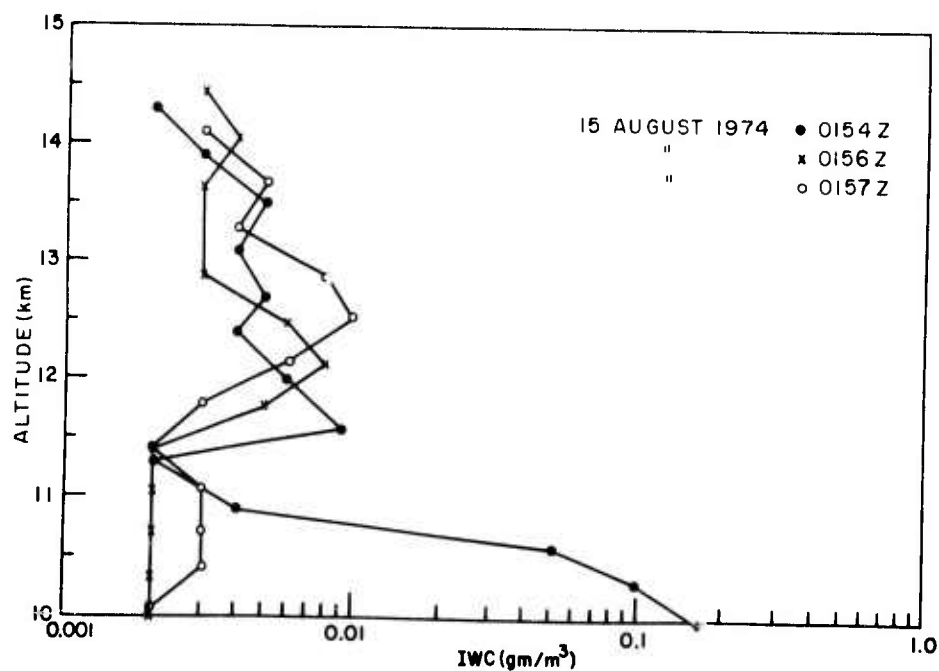


Figure A22. Ice Water Content vs Altitude; 15 August 1974; Trajectory Scans

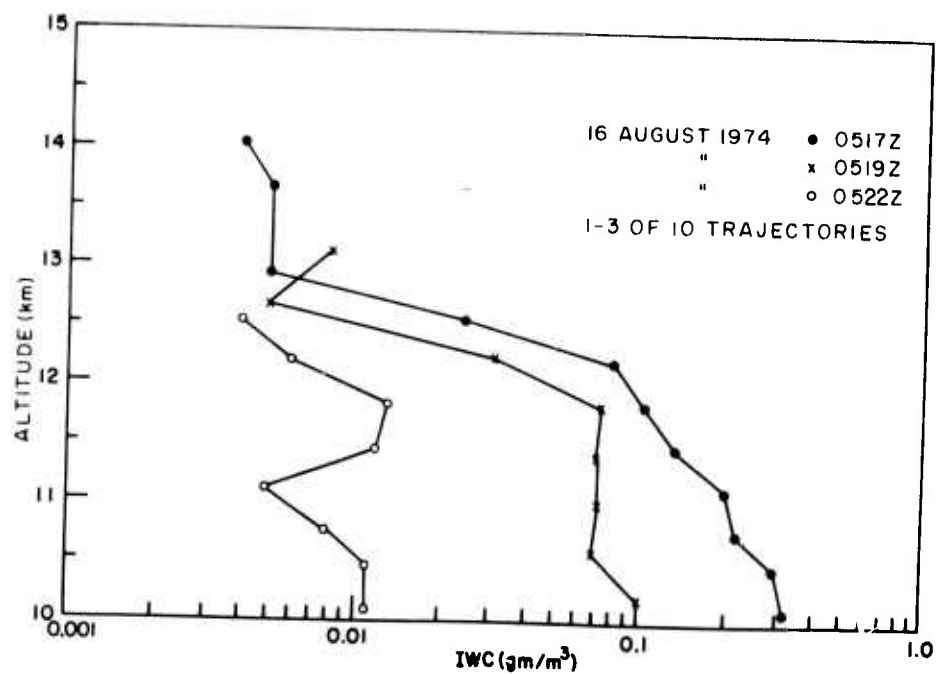


Figure A23. Ice Water Content vs Altitude; 16 August 1974 Trajectory Scans

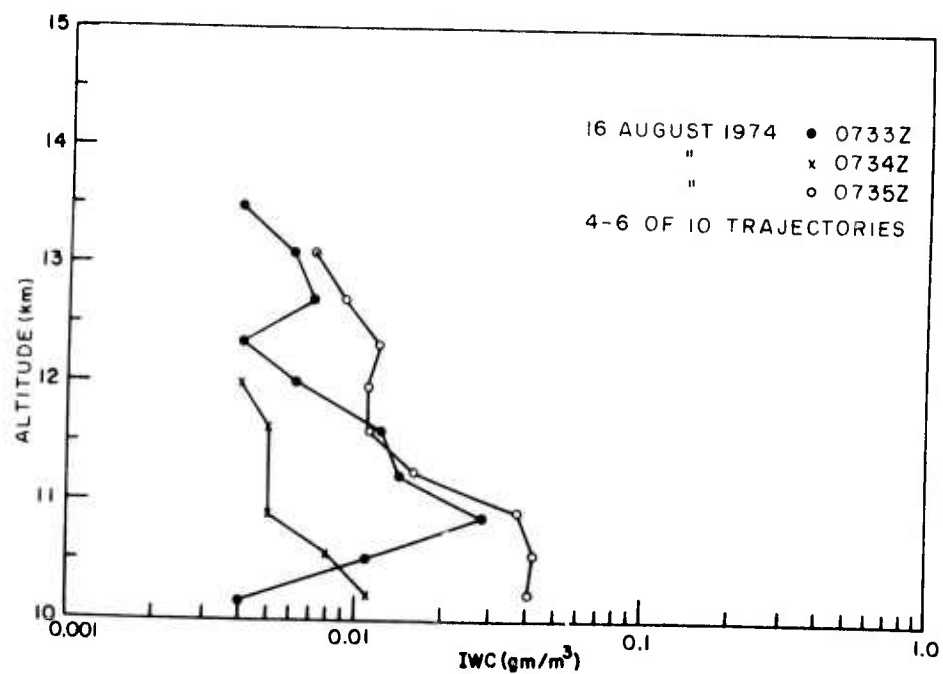


Figure A24. Ice Water Content vs Altitude; 16 August 1974; Trajectory Scans

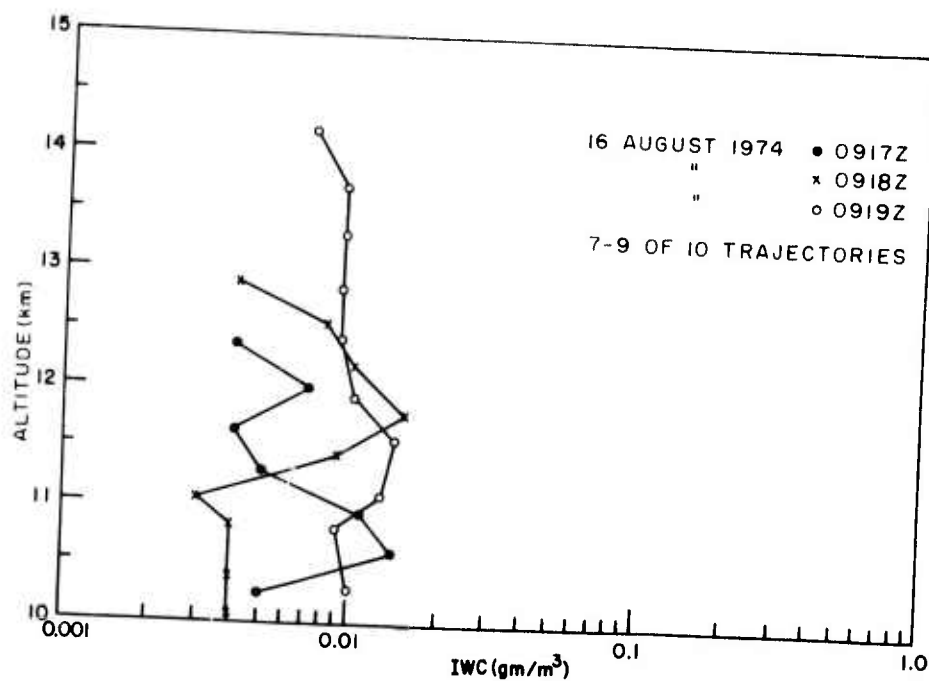


Figure A25. Ice Water Content vs Altitude; 16 August 1974;
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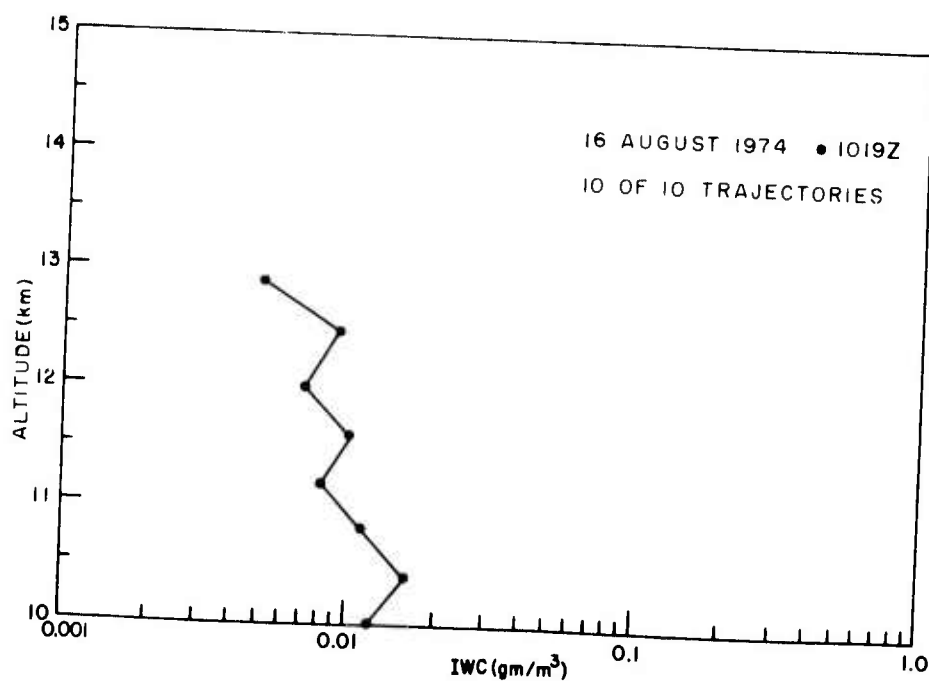


Figure A26. Ice Water Content vs Altitude; 16 August 1974;
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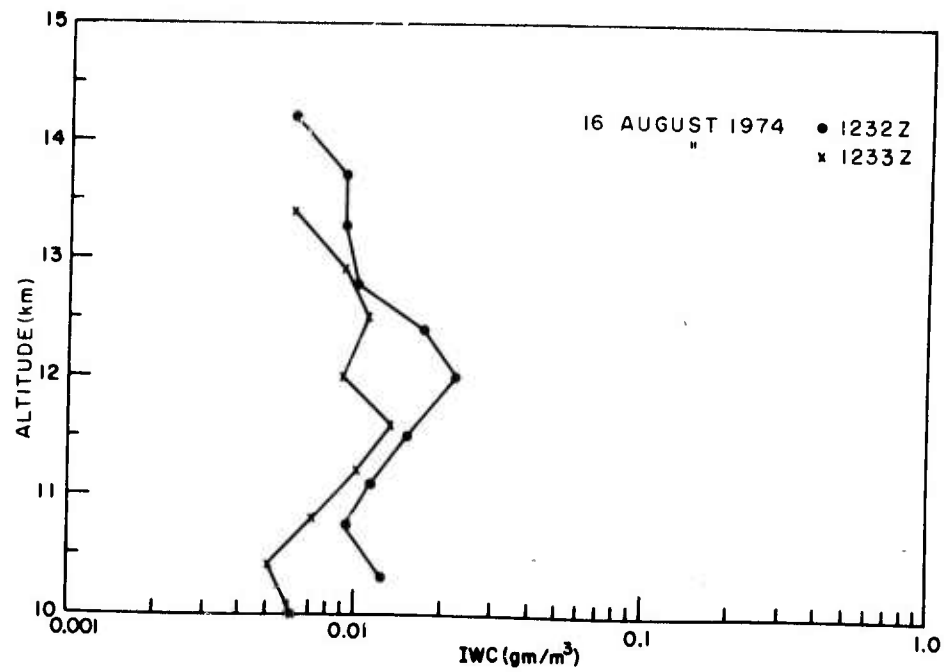


Figure A27. Ice Water Content vs Altitude; 16 August 1974; Trajectory Scans

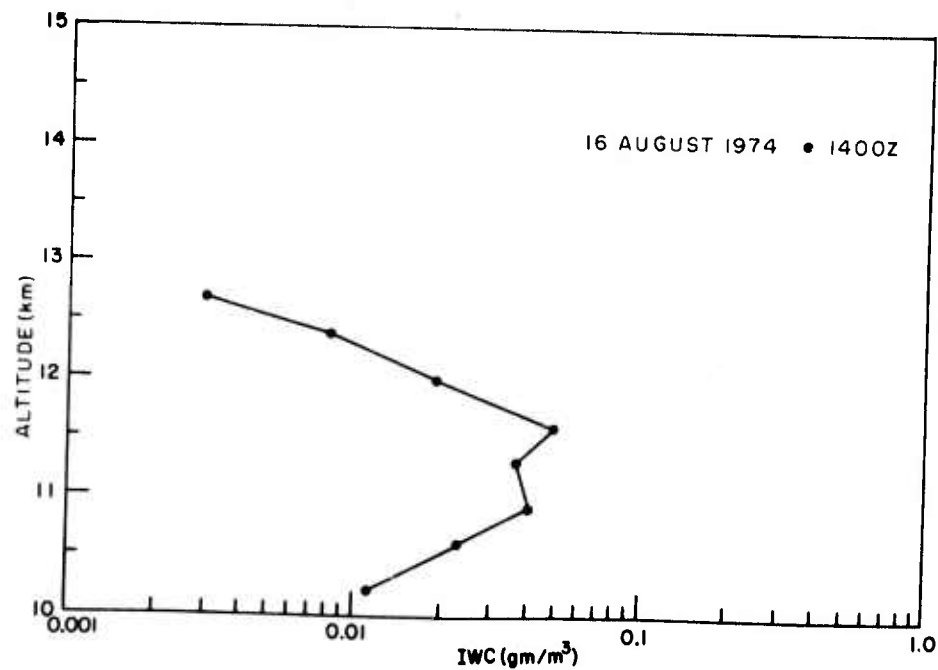


Figure A28. Ice Water Content vs Altitude; 16 August 1974; Trajectory Scan

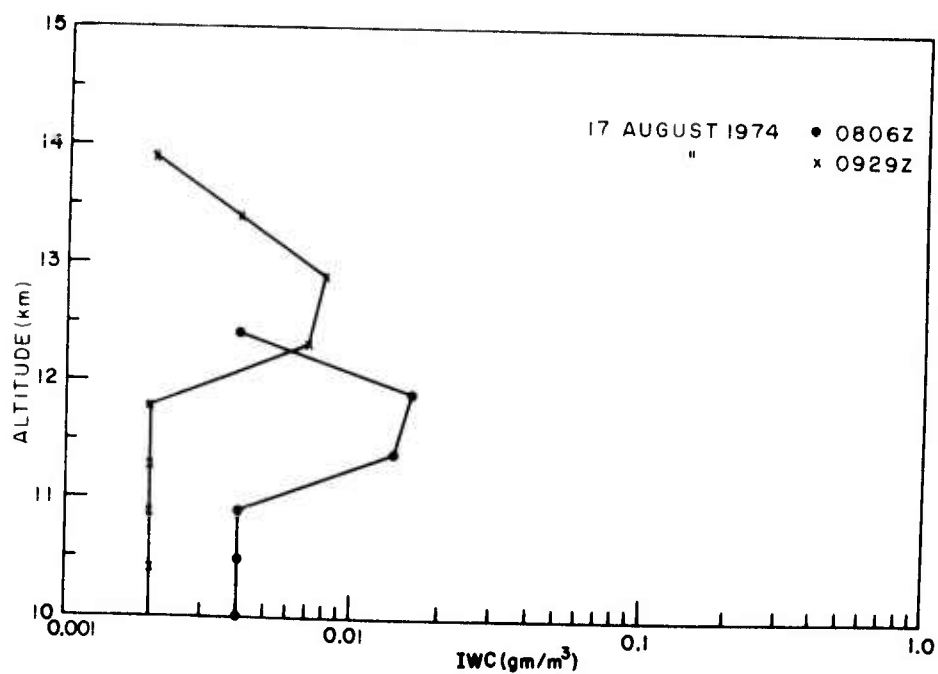


Figure A29. Ice Water Content vs Altitude; 17 August 1974; Trajectory Scans

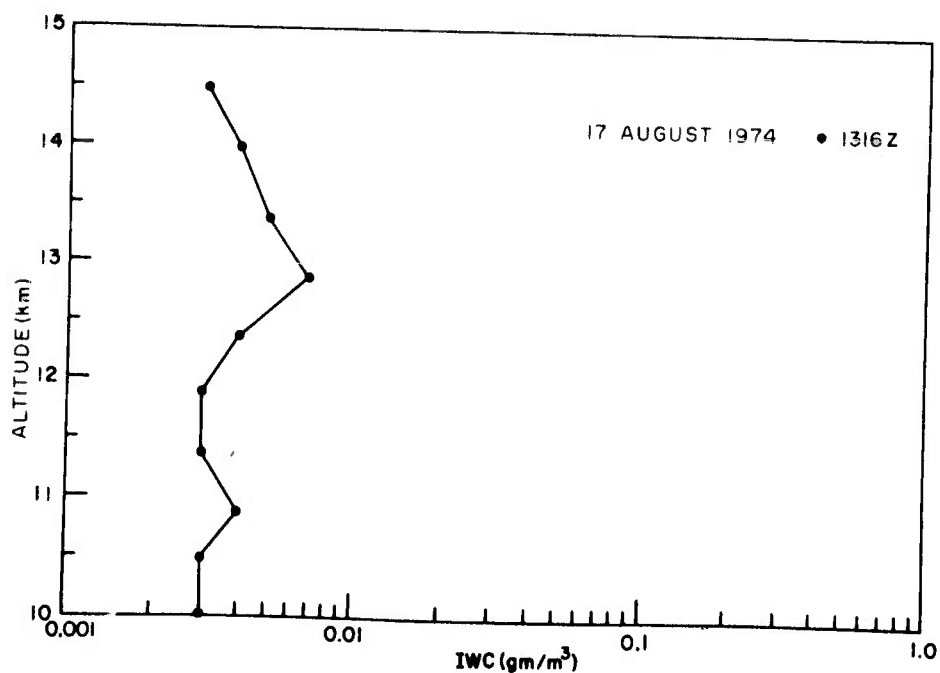


Figure A30. Ice Water Content vs Altitude; 17 August 1974; Trajectory Scan

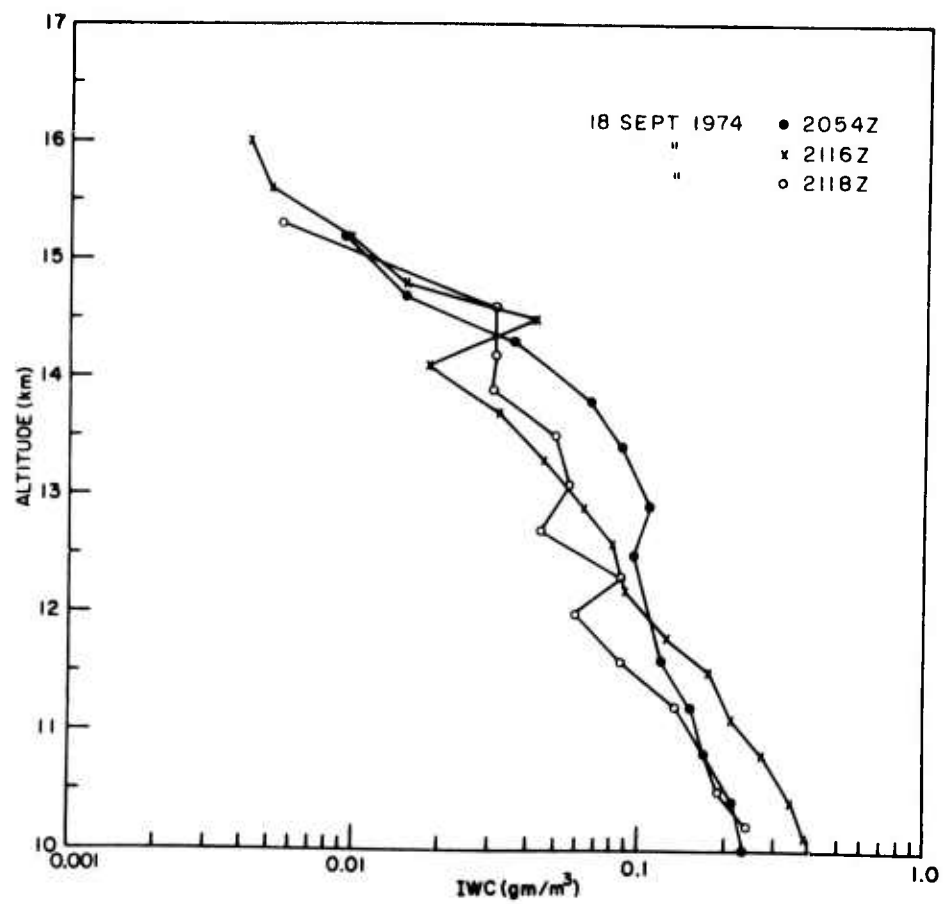


Figure A21. Ice Water Content vs Altitude; 18 September 1974; Trajectory Scans

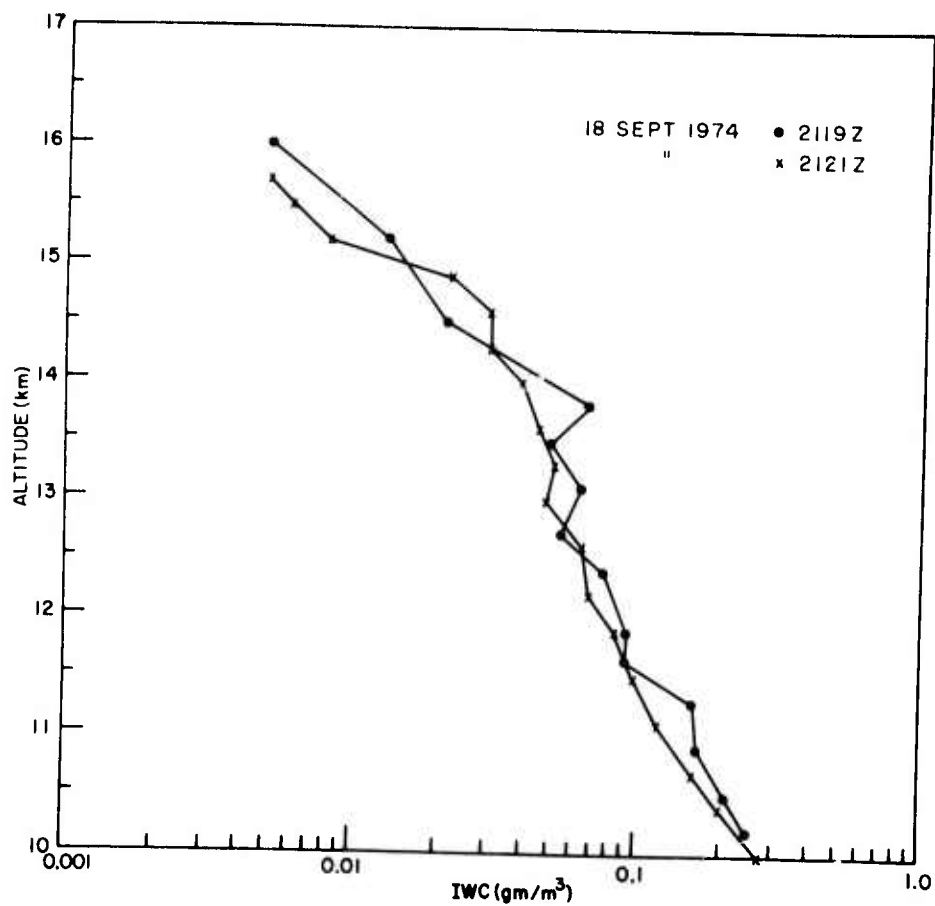


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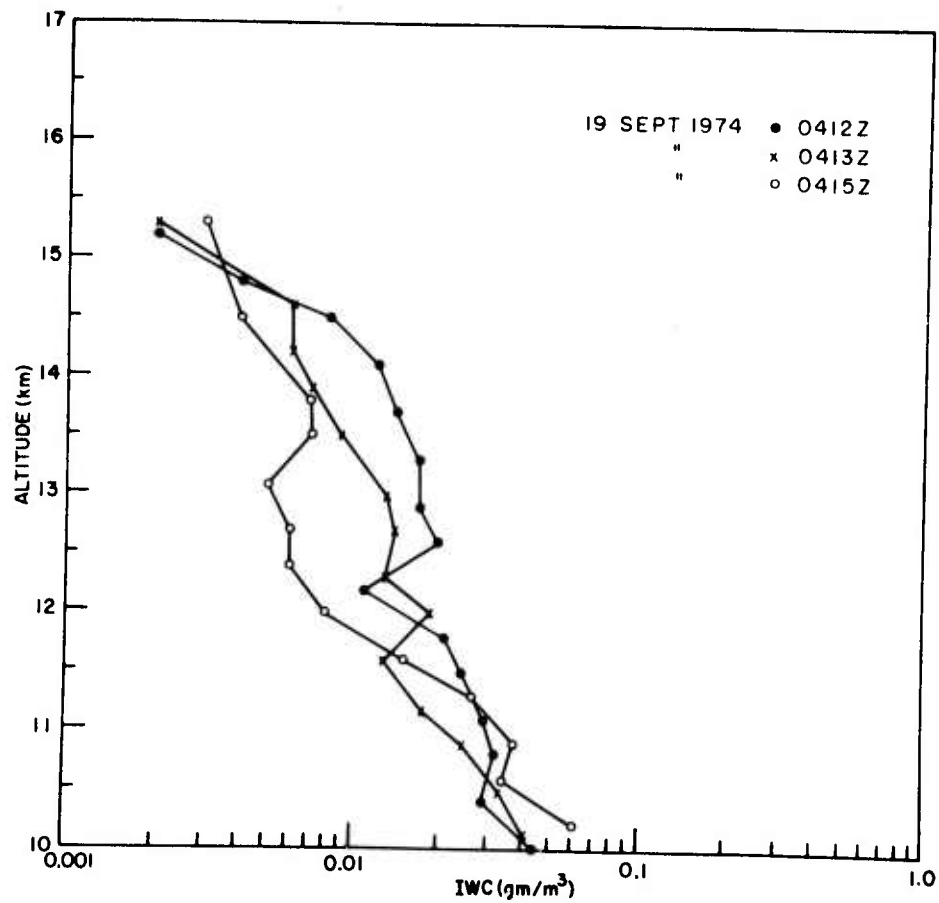


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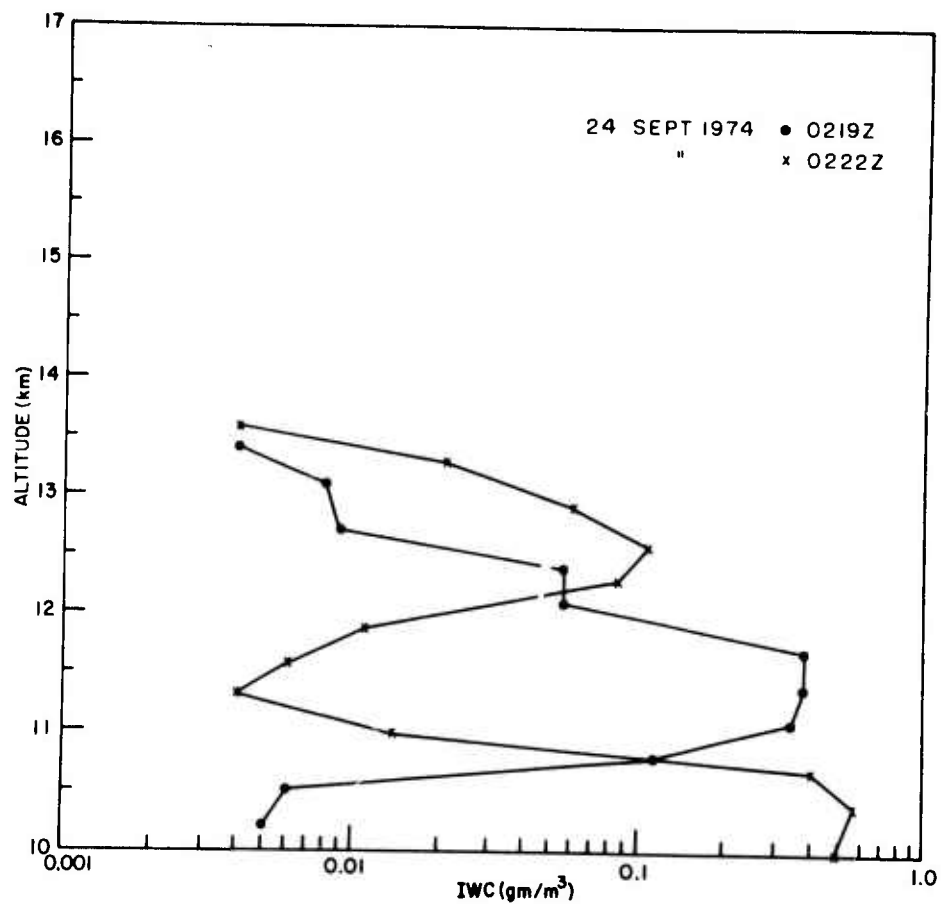


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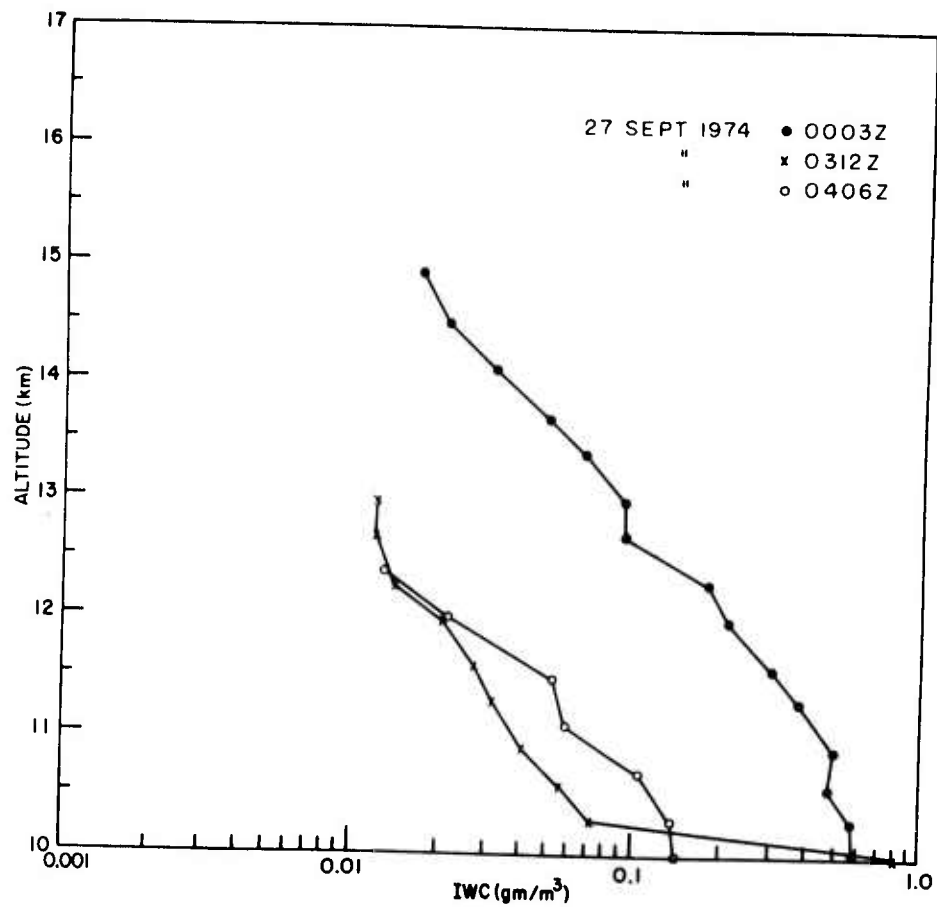


Figure A35. Ice Water Content vs Altitude; 27 September 1974; Trajectory Scans

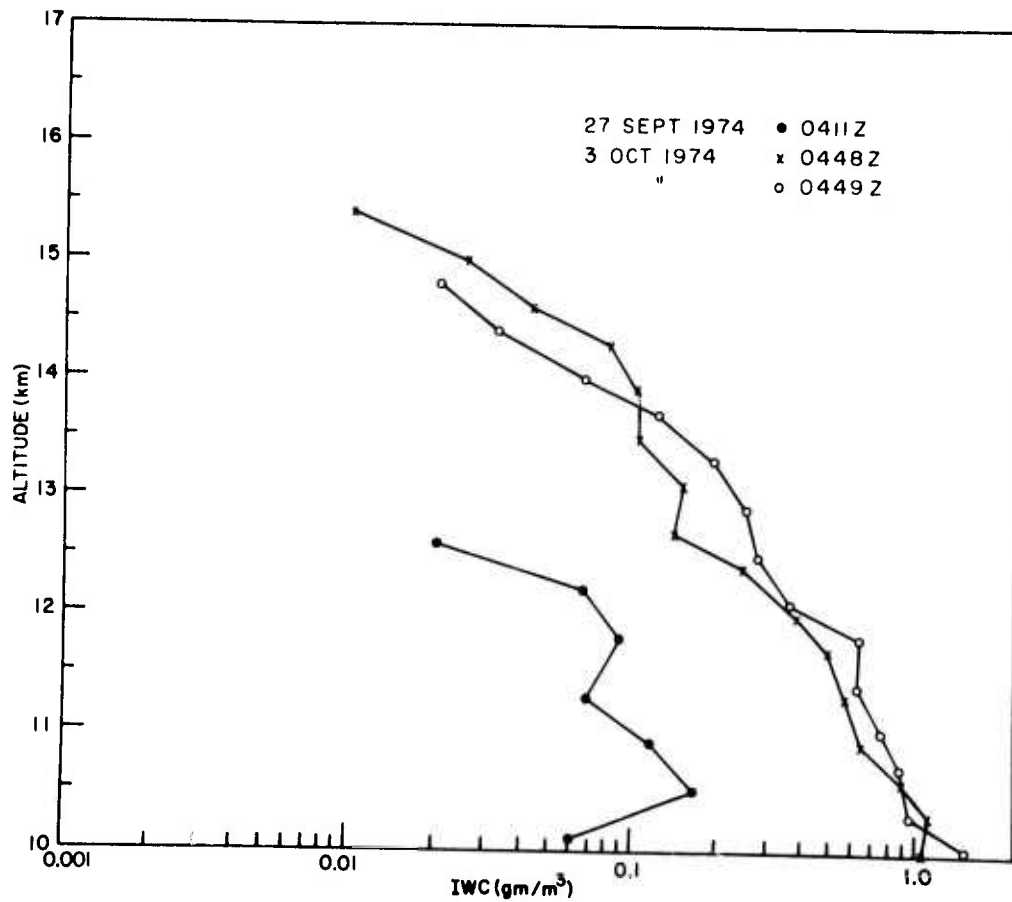


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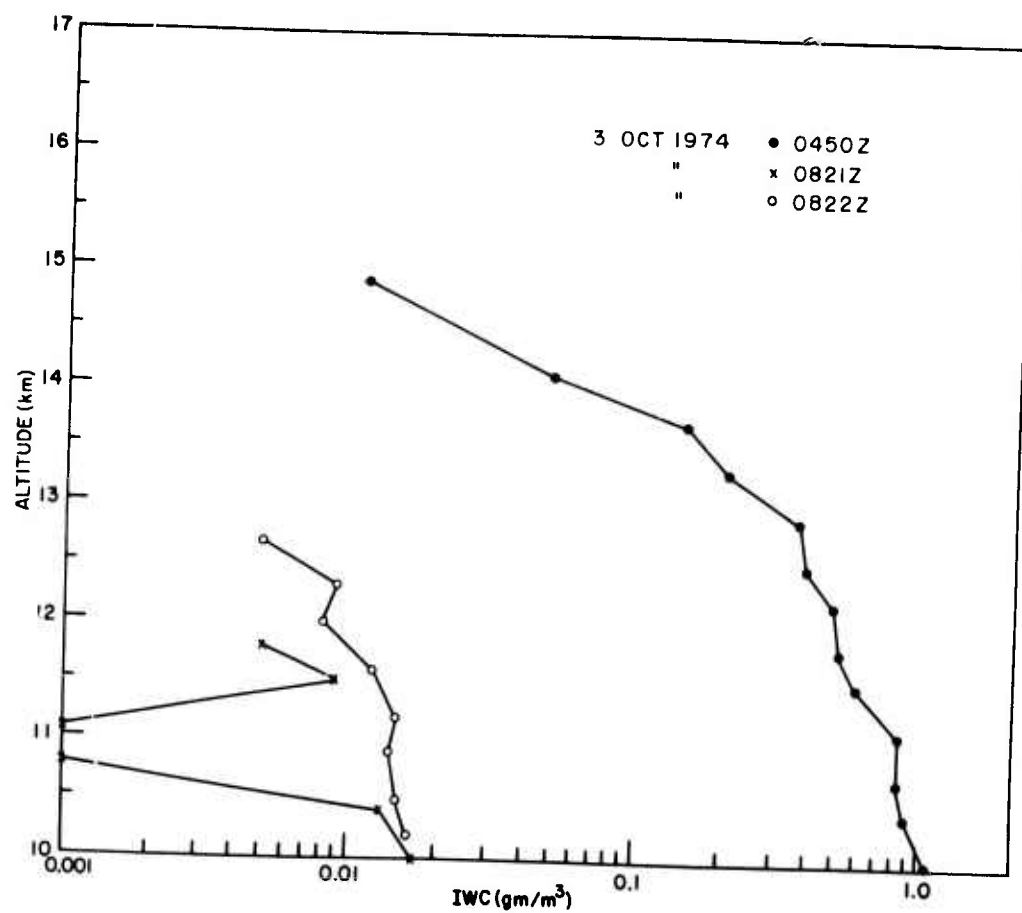


Figure A37. Ice Water Content vs Altitude; 3 October 1974; Trajectory Scans

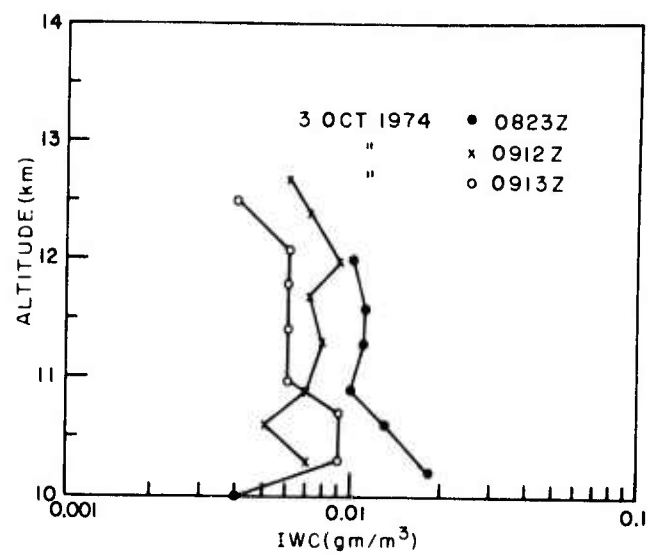


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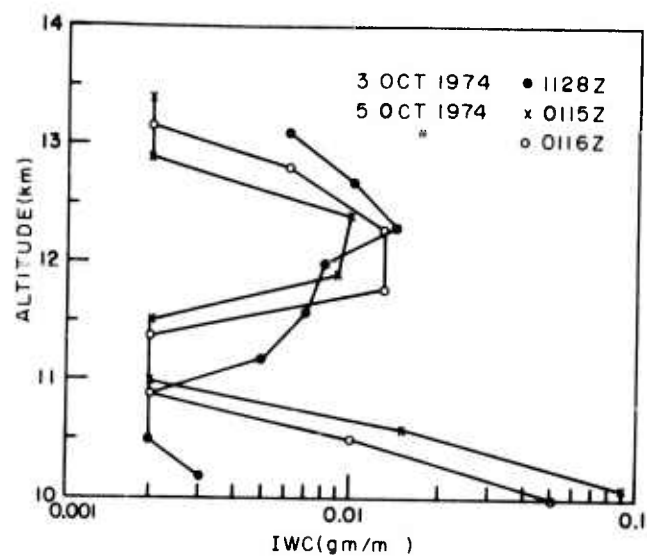


Figure A39. Ice Water Content vs Altitude;
3 October 1974; Trajectory Scans

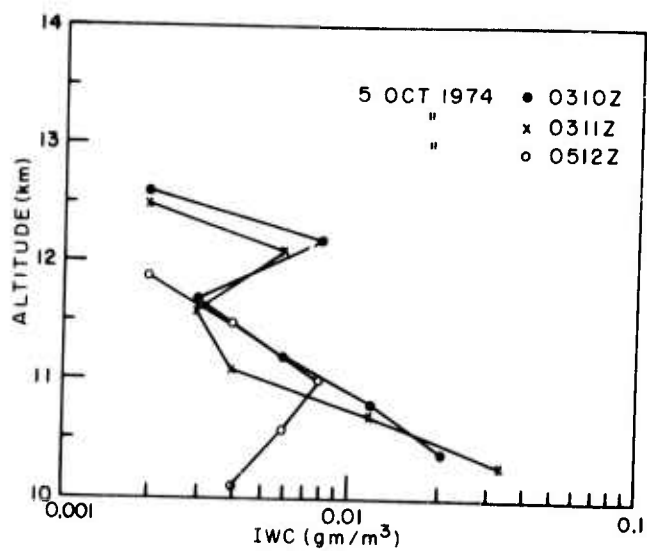


Figure A40. Ice Water Content vs Altitude;
5 October 1974; Trajectory Scans

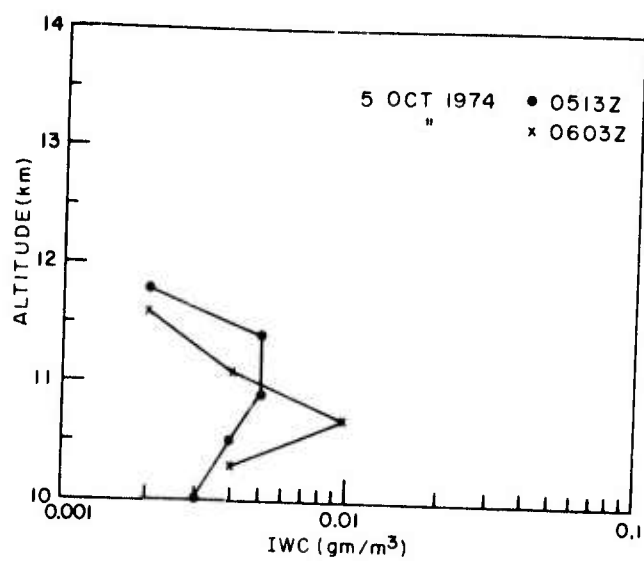


Figure A41. Ice Water Content vs Altitude;
5 October 1974; Trajectory Scans

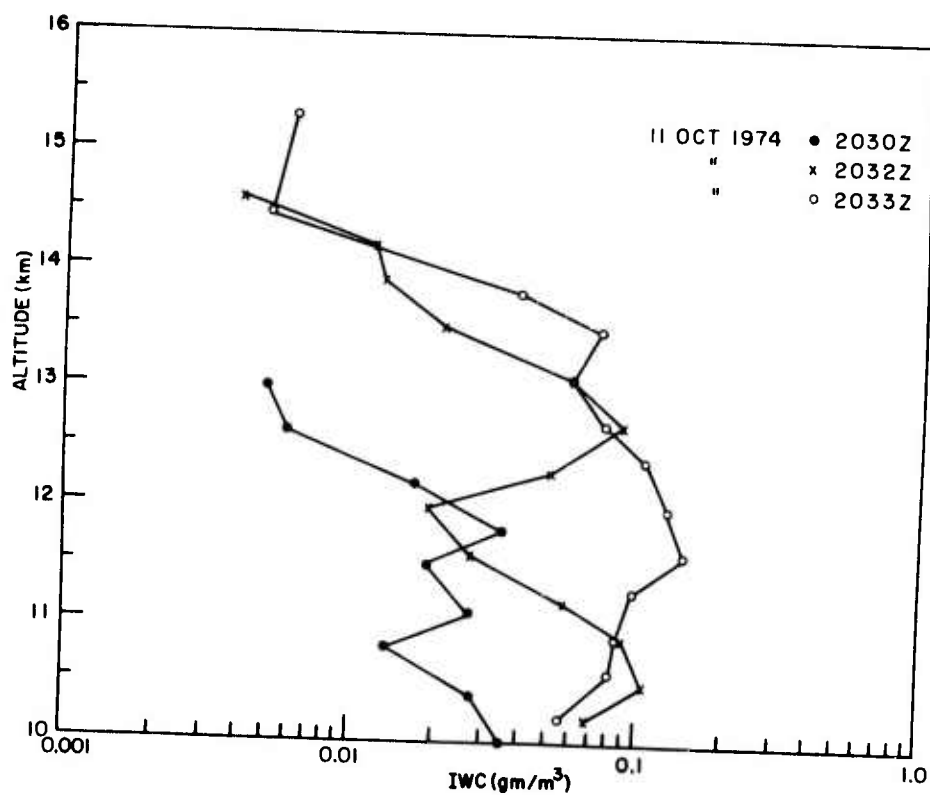


Figure A42. Ice Water Content vs Altitude; 11 October 1974; Trajectory Scans

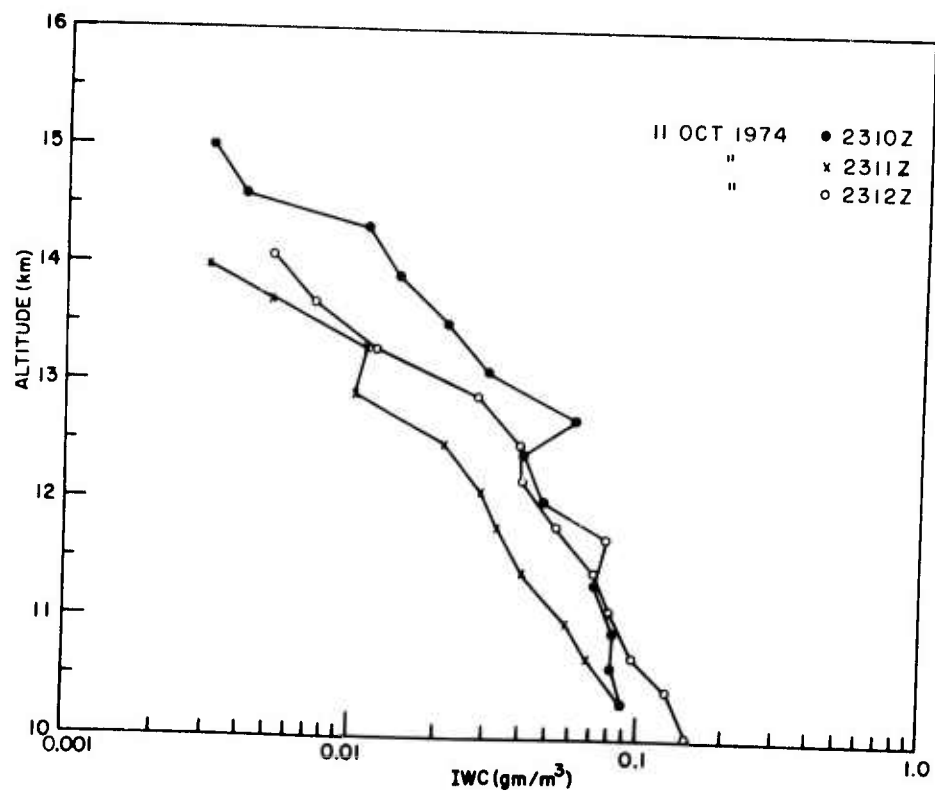


Figure A43. Ice Water Content vs Altitude; 11 October 1974; Trajectory Scans

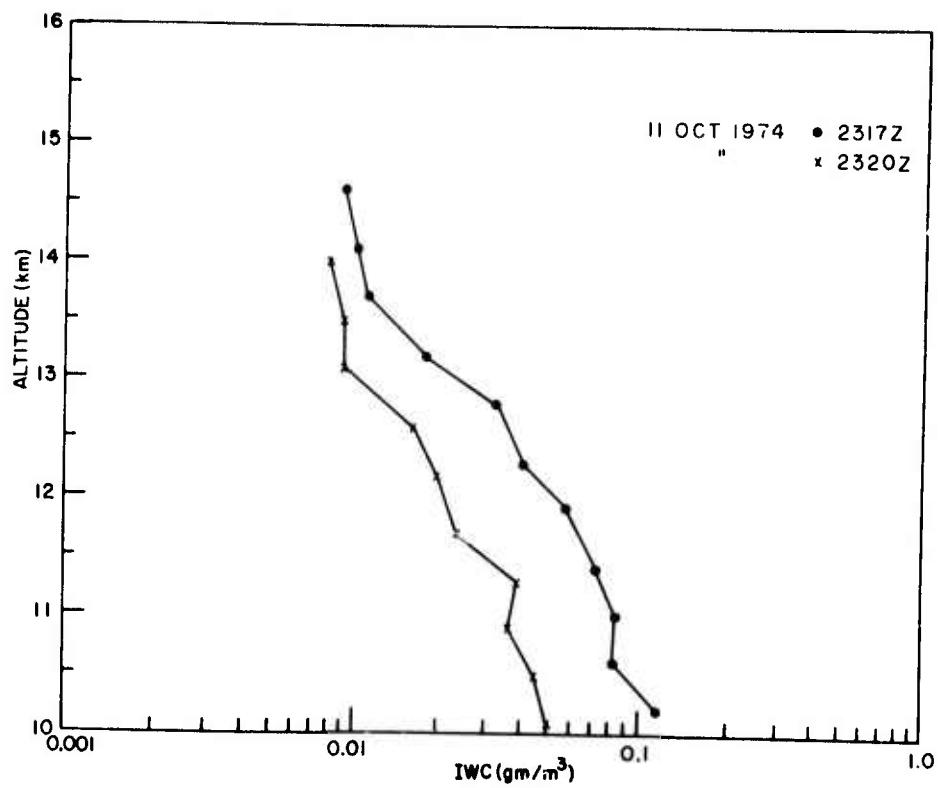


Figure A44. Ice Water Content vs Altitude; 11 October 1974; Trajectory Scans

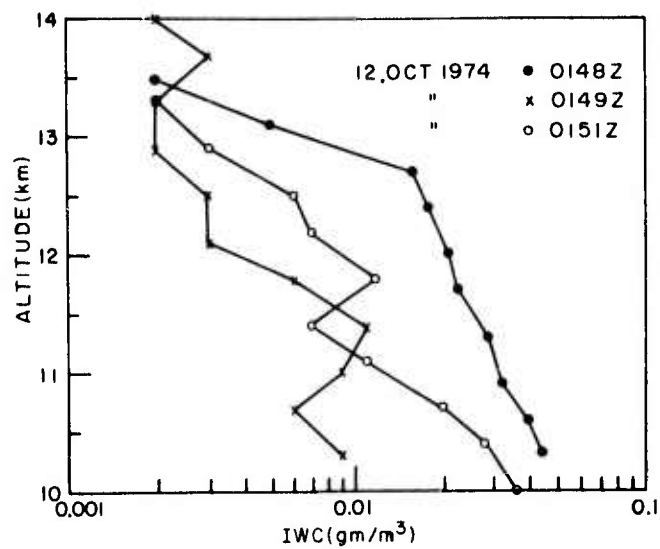


Figure A45. Ice Water Content vs Altitude;
12 October 1974; Trajectory Scans

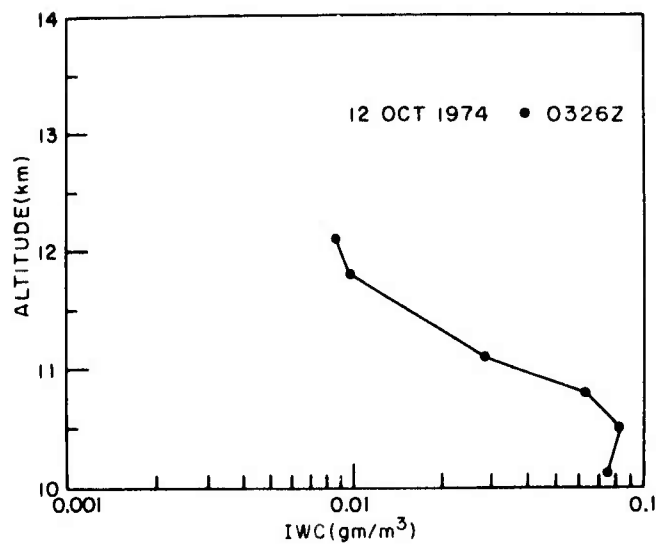


Figure A46. Ice Water Content vs Altitude;
12 October 1975; Vertical Scan

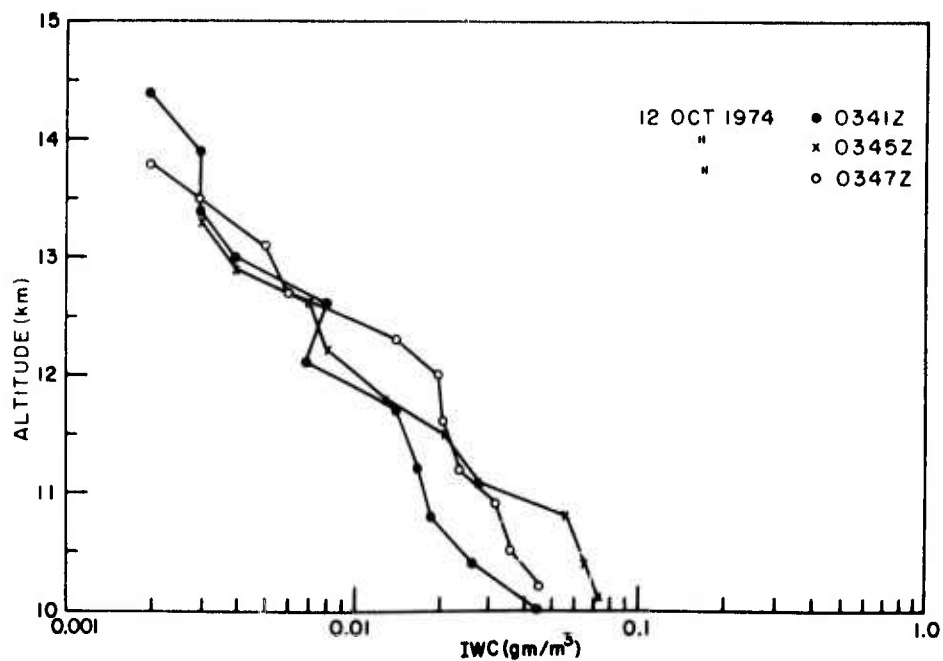


Figure A47. Ice Water Content vs Altitude; 12 October 1974; Trajectory Scans

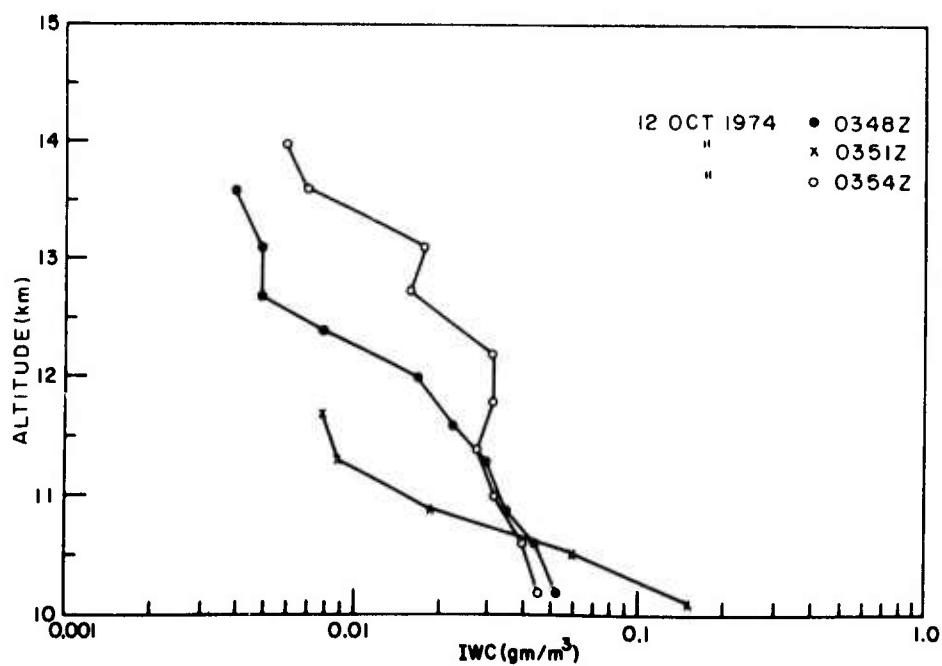


Figure A48. Ice Water Content vs Altitude; 12 October 1974; Trajectory Scans

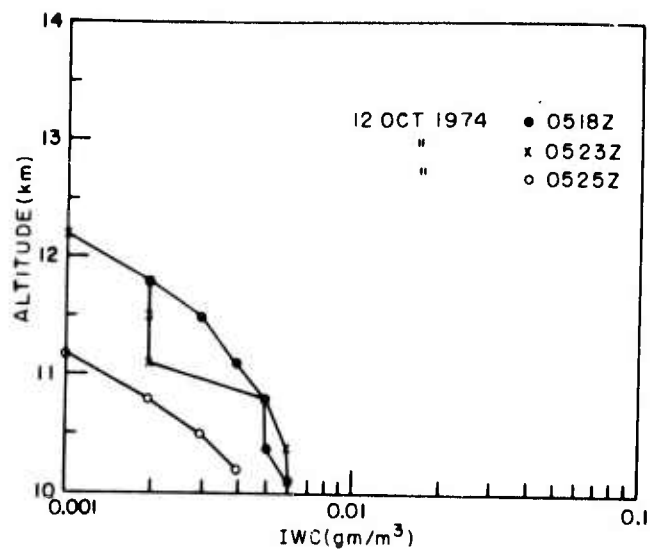


Figure A49. Ice Water Content vs Altitude;
12 October 1974; Trajectory Scans

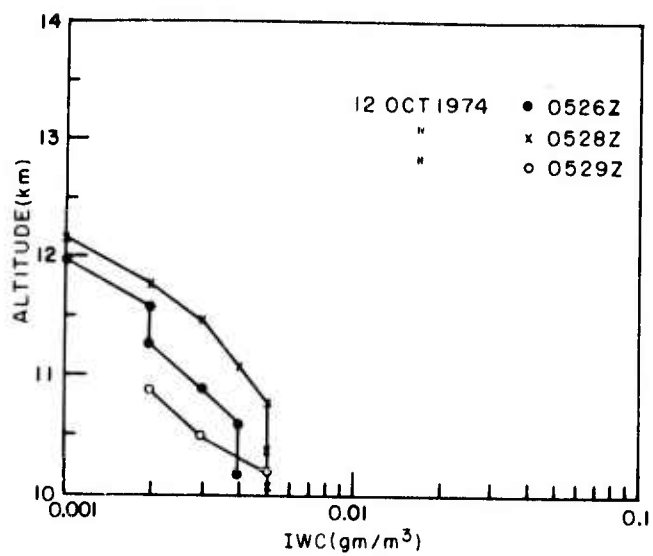


Figure A50. Ice Water Content vs Altitude;
12 October 1974; Trajectory Scans

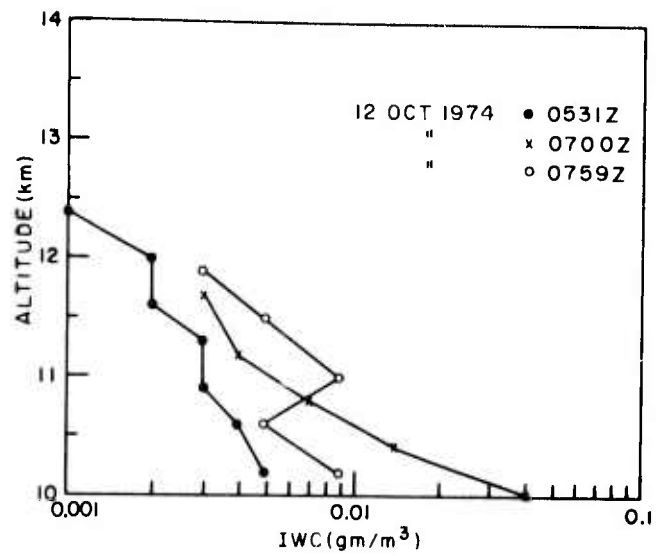


Figure A51. Ice Water Content vs Altitude;
12 October 1974; Trajectory Scans

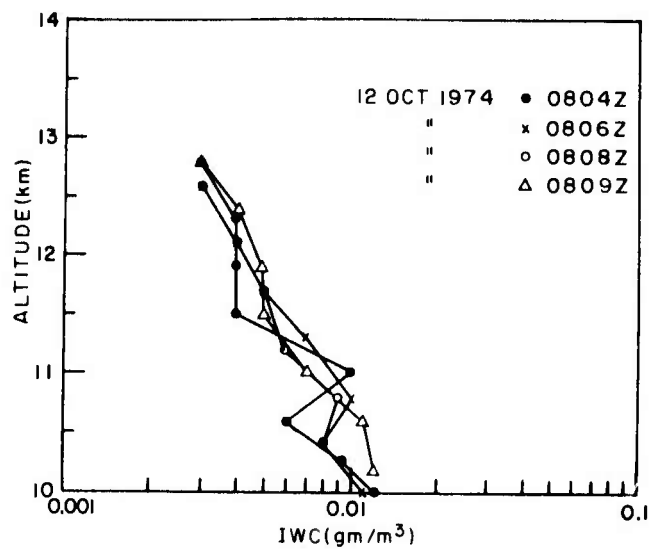


Figure A52. Ice Water Content vs Altitude;
12 October 1974; Trajectory Scans

Appendix B

Maximum IWC Envelope

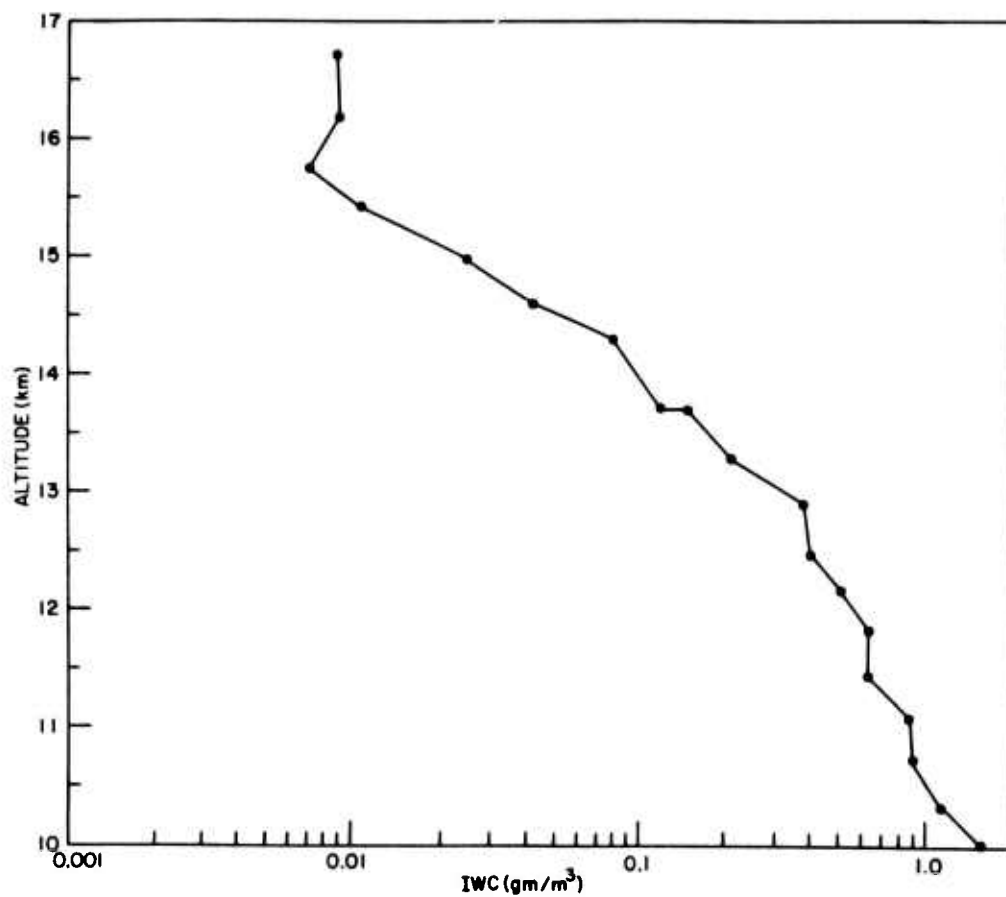


Figure B1. Ice Water Content Envelope; March to October 1974

Appendix C
Time Plots of IWC at Selected Altitudes
(March to October 1974)

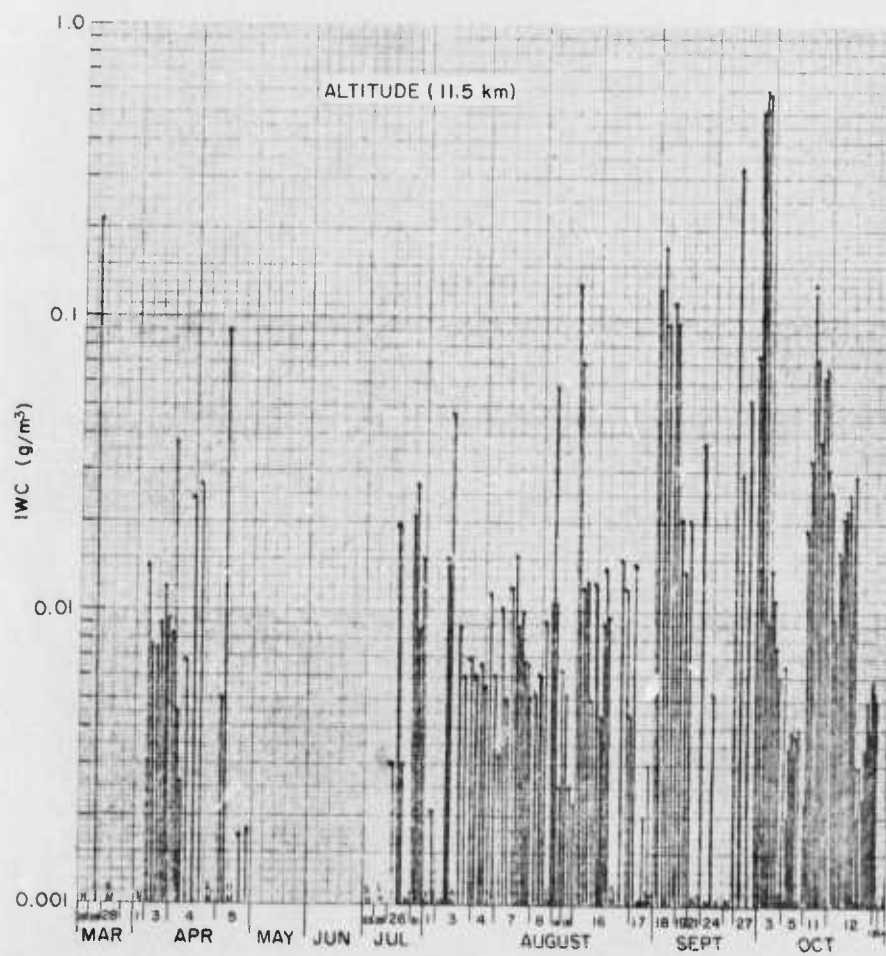


Figure C1. Ice Water Content at 11.5 km

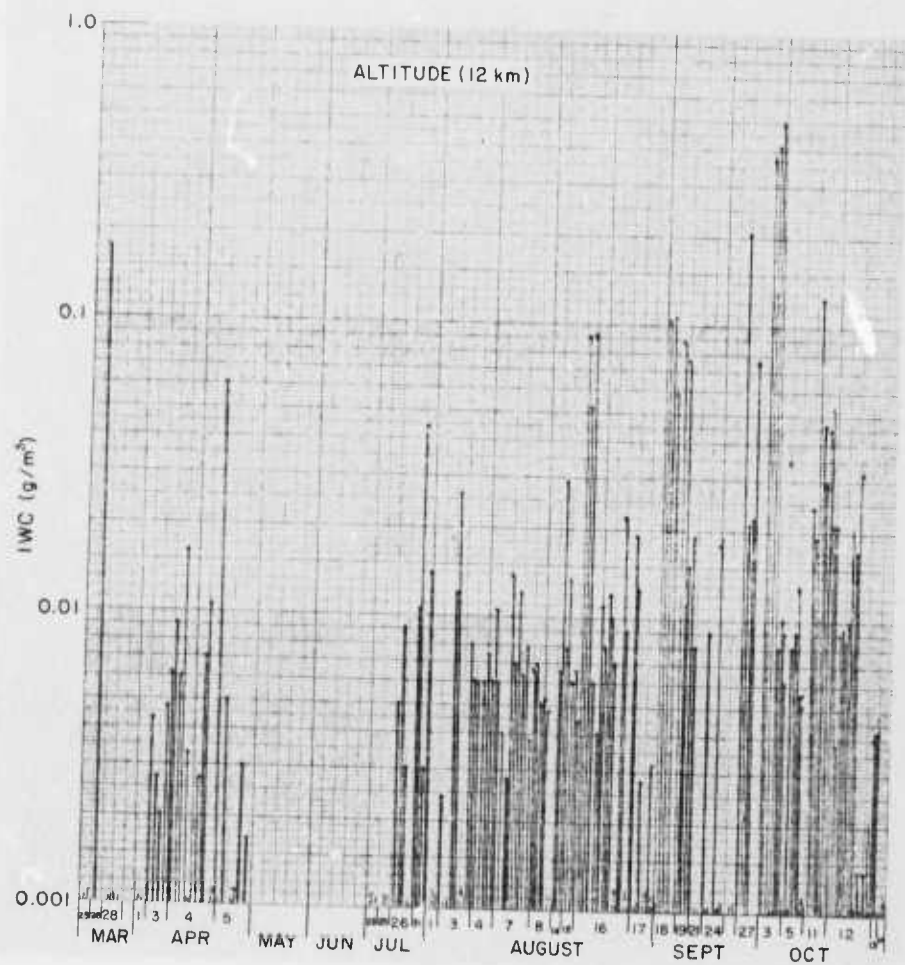


Figure C2. Ice Water Content at 12.0 km

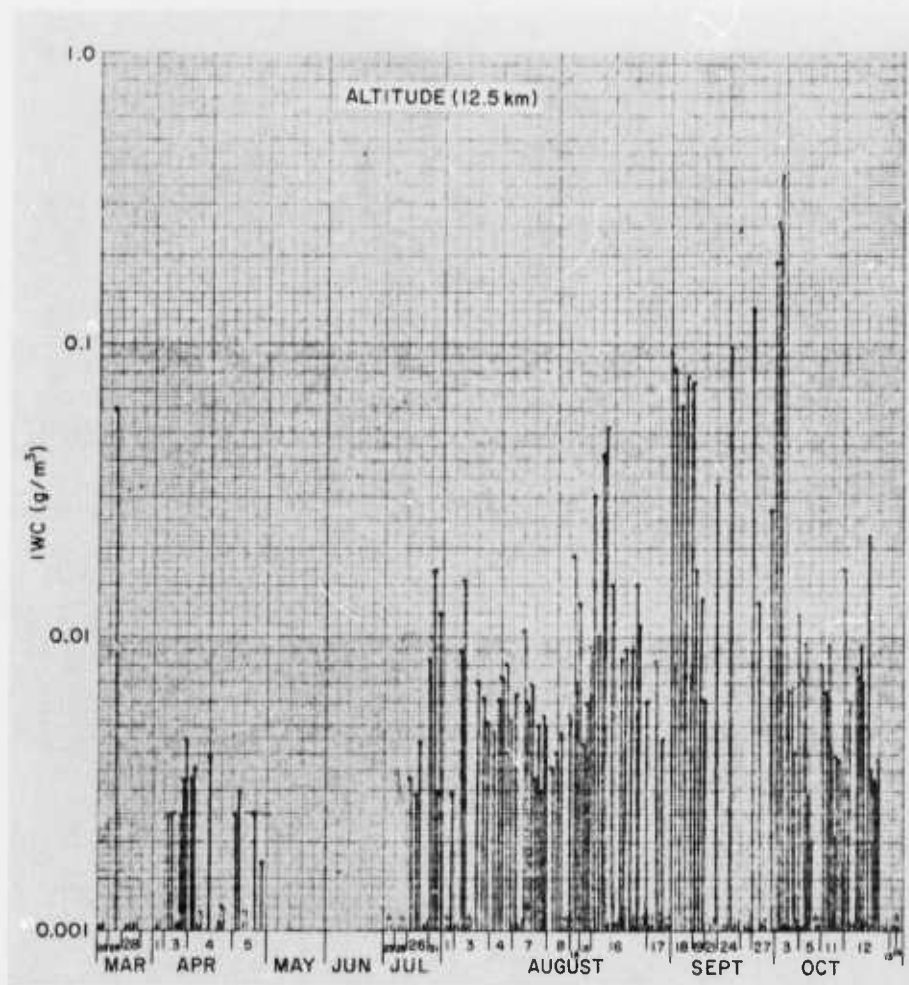


Figure C3. Ice Water Content at 12.5 km

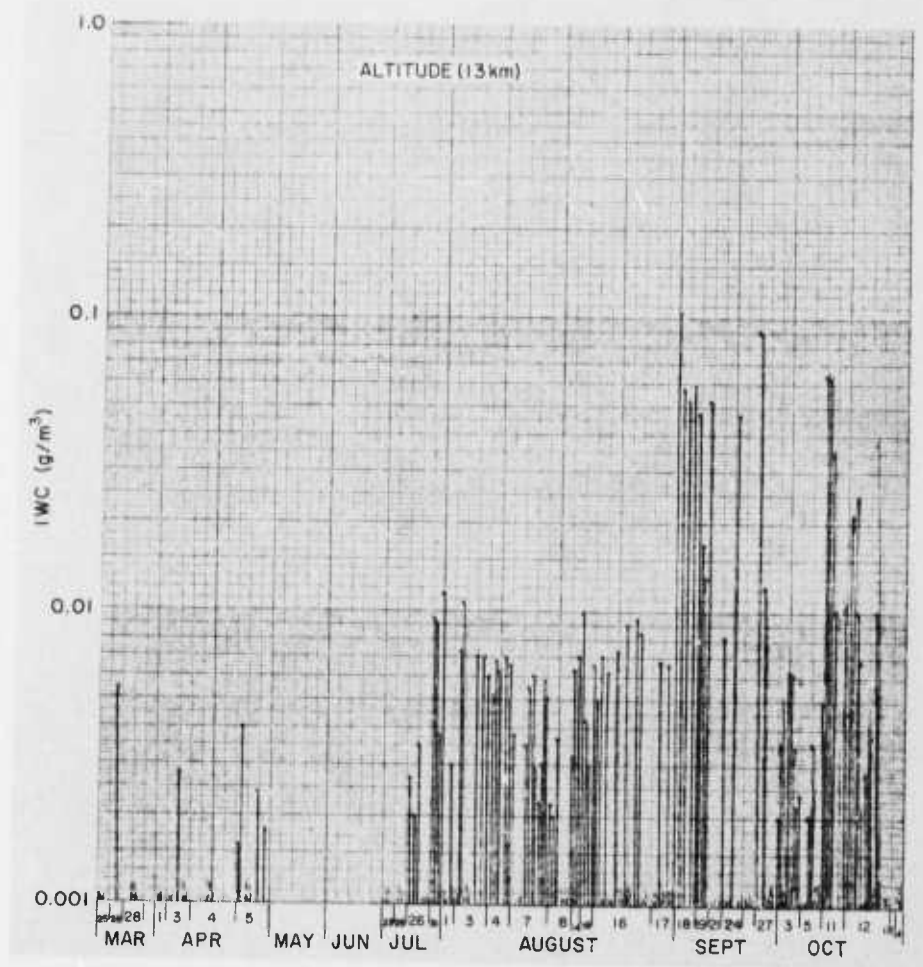


Figure C4. Ice Water Content at 13.0 km

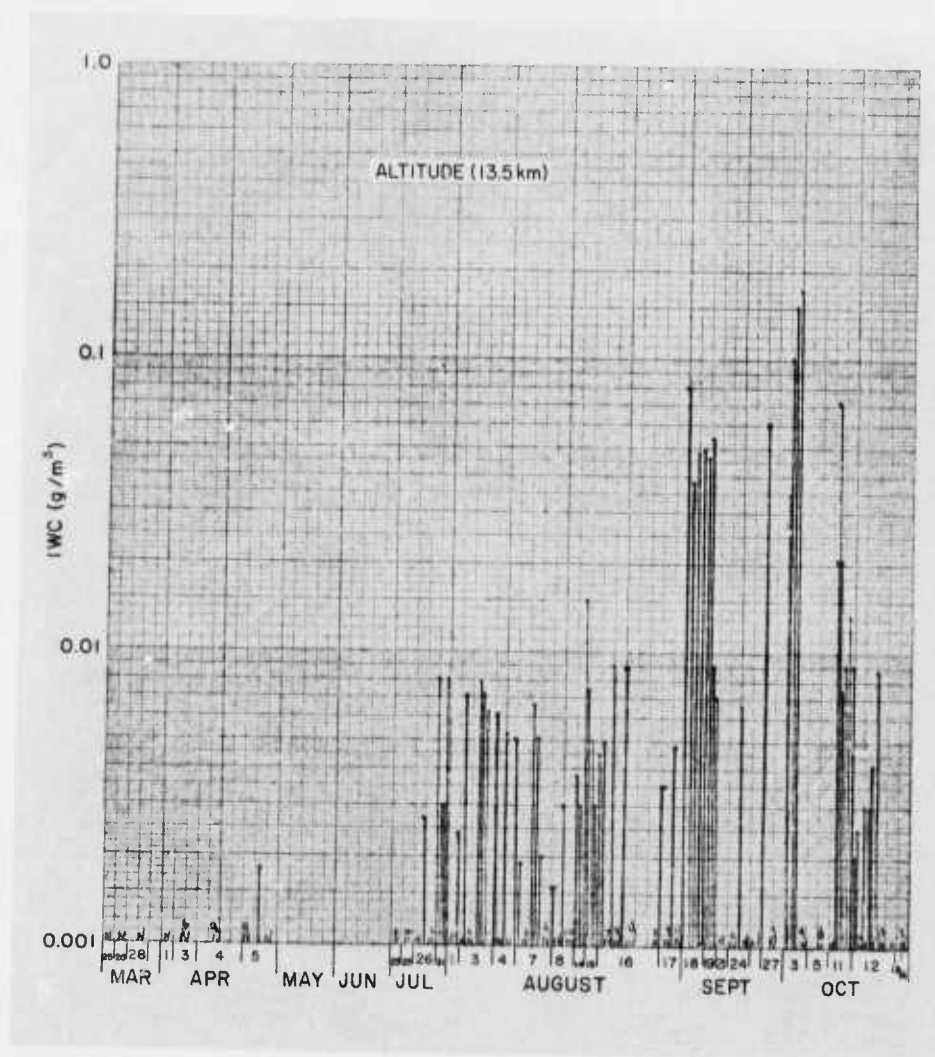


Figure C5. Ice Water Content at 13.5 km

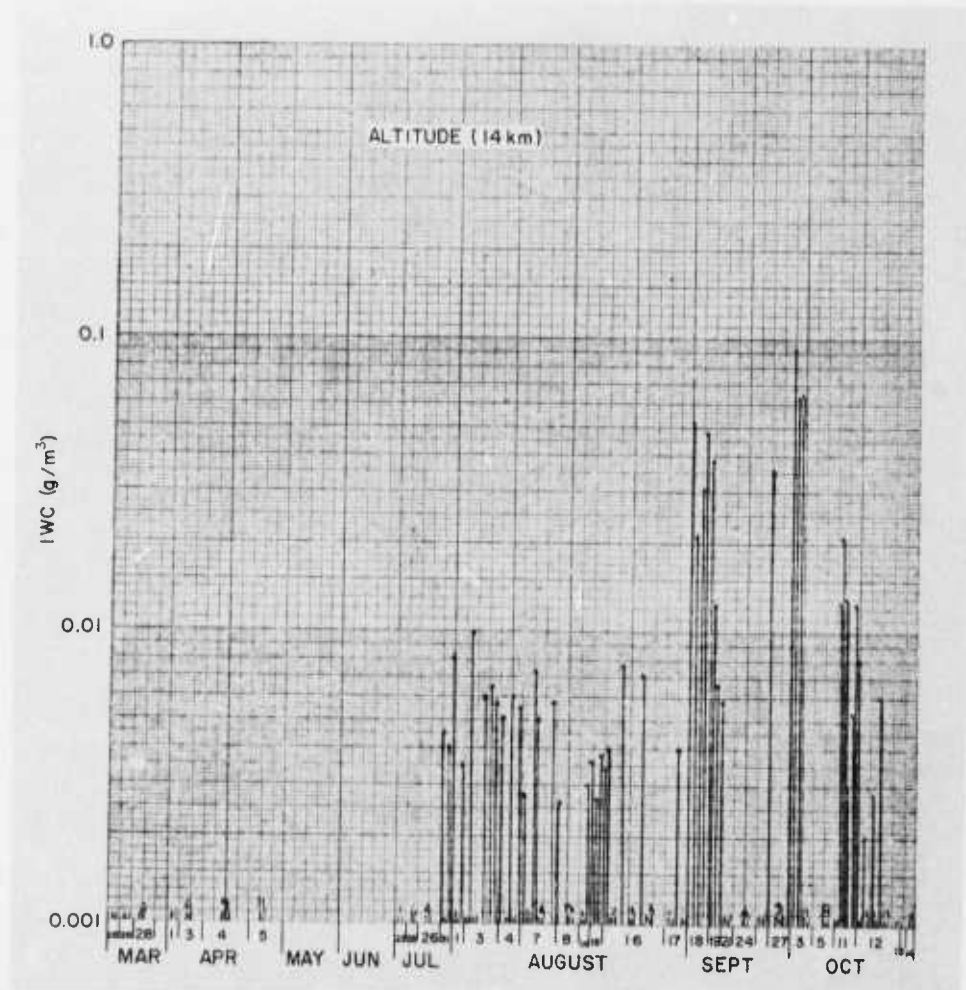


Figure C6. Ice Water Content at 14.0 km

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Appendix D

List of ALCOR Scans

ALCOR SCANS, 1974

0148Z	25 March	Vert. R = 15 km	Noise .03	Not Plotted
2126Z	26 March	Vert. R = 48 km	Noise .002	Plotted
2053Z	28 March	Vert. R = 43 km	All noise .002	Not Plotted
2229Z	28 March	Vert. R = 10 km	All noise .003	Not Plotted
2228Z	1 April	Vert. R = 10 km	All noise .003	Not Plotted
0245Z	3 April	Vert. R = 30 km	Noise .003	Plotted
2107Z	3 April	Vert. R = 60 km	Noise .002	Plotted
2128Z	3 April	3 Trajectories	Noise .002	3 Plotted
2247Z	3 April	Vert. R = 30 km	Noise .002	Plotted
0013Z	4 April	Vert. R = 29 km	Noise .002	Plotted
0053Z	4 April	Vert. R = 68 km	Noise .003	Plotted
2107Z	4 April	Vert. R = 73 km	Noise .004	Plotted
2132Z	4 April	3 Trajectories	Noise .002	Plotted
2236Z	4 April	Vert. R = 130 km	Noise .005	Plotted
2313Z	4 April	Vert. R = 130 km	Noise .005	Plotted
2351Z	4 April	Vert. R = 75 km	Noise .003	Plotted
0030Z	5 April	Vert. R = 40 km	Noise .002	Plotted
0125Z	5 April	Vert. R = 68 km	Noise .003	Plotted
0154Z	5 April	6 Trajectories	All noise .002	Not Plotted
0203Z	5 April	3 Trajectories	Noise .002	Plotted
0259Z	23 July	Vert. R = 33 km	Noise above 6 km .002	Not Plotted
2249Z	23 July	Vert. R = 42 km	All noise above 4 km .002	Not Plotted
0102Z	25 July	3 Trajectories (Test)	All noise	Not Plotted
0126Z	25 July	3 Trajectories (Test)	All noise	Not Plotted
0303Z	26 July	3 Trajectories	Noise .003	Plotted
0307Z	26 July	Vert. Scan 1 pt		Plotted
0130Z	31 July	3 Trajectories	Noise .003	Plotted
0154Z	31 July	Vert. R = 77 km	Noise .004	Plotted
0117Z	1 Aug	3 Trajectories	2 all noise Noise .002	2 Not Plotted 1 Plotted
0245Z	3 Aug	2 Trajectories	1 trans. Down 1 noise .008	Not Plotted Plotted
2058Z	3 Aug	Vert. R = 130 km	Noise .008	Plotted
2123Z	3 Aug	3 Trajectories	All noise .003	Not Plotted
2127Z	3 Aug	Vert. R = 13 km	Noise .004	Not Plotted
2150Z	3 Aug	3 Trajectories	Noise .006	Plotted
0022Z	4 Aug	5 Trajectories	Noise .006	Plotted

ALCOR SCANS, 1974 (Cont)

0820Z	7 Aug	3 Trajectories	Noise .003	Plotted
0828Z	7 Aug	2 Trajectories	Noise .006	Plotted
1022Z	7 Aug	3 Trajectories	Noise .002	Plotted
1047Z	7 Aug	1 Trajectory	Noise .007	Plotted
1107Z	7 Aug	1 Trajectory	Noise .005	Plotted
0809Z	8 Aug	3 Trajectories	Noise .003	Plotted
0817Z	8 Aug	2 Trajectories	All noise .007	Not Plotted
1014Z	8 Aug	3 Trajectories	All noise .003	Not Plotted
1048Z	8 Aug	2 Trajectories	All noise .007	Not Plotted
1203Z	8 Aug	3 Trajectories	All noise .003	Not Plotted
0300Z	14 Aug	2 Trajectories	Noise .003	Plotted
2302Z	14 Aug	2 Trajectories	Noise .003	Plotted
0154Z	15 Aug	3 Trajectories	Noise .003	Plotted
0517Z	16 Aug	3 Trajectories	Noise .004	Plotted
0733Z	16 Aug	3 Trajectories	Noise .004	Plotted
0917Z	16 Aug	3 Trajectories	Noise .003	Plotted
1019Z	16 Aug	1 Trajectory	Noise .005	Plotted
1129Z	16 Aug	1 Trajectory	Noise .004	Not Plotted
1131Z	16 Aug	1 Trajectory	Noise .003	Not Plotted
1132Z	16 Aug	1 Trajectory	Noise .003	Not Plotted
1135Z	16 Aug	1 Trajectory	Noise .008	Not Plotted
1138Z	16 Aug	1 Trajectory	Noise .007	Not Plotted
1211Z	16 Aug	1 Trajectory	Noise .003	Not Plotted
1212Z	16 Aug	1 Trajectory	Noise .002	Not Plotted
1214Z	16 Aug	1 Trajectory	Noise .004	Not Plotted
1232Z	16 Aug	2 Trajectories	Noise .007	Plotted
1358Z	16 Aug	1 Trajectory	Noise .003	Not Plotted
1359Z	16 Aug	1 Trajectory	Noise .002	Not Plotted
1434Z	16 Aug	1 Trajectory	Noise .003	Plotted
0806Z	17 Aug	1 Trajectory	Noise .004	Plotted
0807Z	17 Aug	1 Trajectory	Noise .004	Not Plotted
0929Z	17 Aug	1 Trajectory	Noise .002	Plotted
0930Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
0131Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1315Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1316Z	17 Aug	1 Trajectory	Noise .004	Plotted
1318Z	17 Aug	1 Trajectory	Noise .004	Not Plotted
1452Z	17 Aug	1 Trajectory	Noise .003	Not Plotted

ALCOR SCANS, 1974 (Cont)

1453Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1455Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1651Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1653Z	17 Aug	1 Trajectory	Noise .004	Not Plotted
1654Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1656Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1657Z	17 Aug	1 Trajectory	Noise .004	Not Plotted
1658Z	17 Aug	1 Trajectory	Noise .003	Not Plotted
1659Z	17 Aug	1 Vert. R = 6 km	Noise .004	Not Plotted
2054Z	18 Sept	3 Trajectories	Noise .002	Plotted
2119Z	18 Sept	2 Trajectories	Noise .005	Plotted
0412Z	19 Sept	3 Trajectories	Noise .002	Plotted
0220Z	21 Sept	1 Trajectory	All noise .002	Not Plotted
0219Z	24 Sept	1 Trajectory	Noise .002	Plotted
0221Z	24 Sept	1 Trajectory	All Noise .002	Not Plotted
0222Z	24 Sept	1 Trajectory	Noise .002	Plotted
2346Z	24 Sept	1 Trajectory	All noise .004	Not Plotted
0021Z	26 Sept	1 Trajectory	All noise .004	Not Plotted
0003Z	27 Sept	3 Trajectories	Noise .010	Plotted
0411Z	27 Sept	1 Trajectory	Noise .02	Plotted
0448Z	3 Oct	2 Trajectories	Noise .01	Plotted
0450Z	3 Oct	3 Trajectories	Noise .01 .005 .005	Plotted
0823Z	3 Oct	3 Trajectories	Noise .01 .006 .004	Plotted
0915Z	3 Oct	1 Trajectory	All noise .02	Not Plotted
1127Z	3 Oct	1 Trajectory	All noise .006	Not Plotted
1128Z	3 Oct	1 Trajectory	Noise .003	Plotted
1130Z	3 Oct	1 Trajectory	All noise .04	Not Plotted
0115Z	5 Oct	2 Trajectories	Noise .002	Plotted
0310Z	5 Oct	3 Trajectories	Noise .002	Plotted
0513Z	5 Oct	1 Trajectory	Noise .002	Plotted
0641Z	5 Oct	1 Trajectory	All noise .002	Not Plotted
0643Z	5 Oct	1 Trajectory	Noise .002	Plotted
2030Z	11 Oct	3 Trajectories	Noise .005	Plotted
2310Z	11 Oct	3 Trajectories	Noise .003	Plotted
2317Z	11 Oct	2 Trajectories	Noise .009	Plotted

ALCOR SCANS, 1974 (Cont)

0148Z	12 Oct	3 Trajectories	Noise .002	Plotted
0326Z	12 Oct	Vert. R = 133 km	Noise .009	Plotted
0341Z	12 Oct	3 Trajectories	Noise .002 .003 .002	Plotted
0348Z	12 Oct	3 Trajectories	Noise .004 .008 .006	Plotted
0518Z	12 Oct	3 Trajectories	Noise .002 .001 .001	Plotted
0526Z	12 Oct	3 Trajectories	Noise .001	Plotted
0531Z	12 Oct	3 Trajectories	Noise .001 .003 .003	Plotted
0804Z	12 Oct	4 Trajectories	Noise .003	Plotted
2352Z	13 Oct	1 Trajectory	All noise .004	Not Plotted
0418Z	14 Oct	2 Trajectories	All noise .005	Not Plotted

Abbreviations and Symbols

ABRES	Advanced Ballistic Reentry System
AFCRL	Air Force Cambridge Research Laboratories
ALCOR	ARPA Lincoln C-Band Observables Radar
A. N. T.	Advanced Nosetip Test
ARPA	Advanced Research Planning Agency
CW	Continuous Wave
HP-65	Hewlett Packard 65 Hand-Held Computer
IWC	Ice Water Content (gm m^{-3})
KMR	Kwajalein Missile Range
M	Precipitation Liquid Water Content (gm m^{-3})
PMS	Particle Measuring Systems, Inc., Boulder, Colorado
PRESS	Pacific Range Electromagnetic Signature Studies
PRF	Pulse Repetition Frequency (pulses sec^{-1})
PVM	Production Verification Missile
RV	Reentry Vehicle
SAMSO	Space and Missile Systems Office
WSI	Weather Severity Index ($\text{gm km}^{-2} \text{m}^{-3}$)
Z	Radar Reflectivity Factor ($\text{mm}^6 \text{m}^{-3}$)
Z - M	Relationship between Z and M

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